DIGEST

OF INDUSTRIAL AND TECHNICAL DEVELOPMENTS

D.S.I.R.: New Programmes

THE Department of Scientific and Industrial Research has announced there will be changes in the functions of the Chemical Research Laboratory, which will be known in future as the National Chemical Laboratory. The aim is to concentrate effort on a few limited objectives by undertaking selected fundamental and applied chemical researches of national importance, which could not otherwise be worked on by any existing organisation. Problems will include the determination of the fundamental physico-chemical properties of chemical compounds which are required by chemical engineers for the design of full-scale industrial plant. The related study of purification techniques for supply of pure standard reference samples is also in this category. Studies of corrosion will remain in the programme and development of methods for extracting from low-grade ores elements of interest for atomic energy. We understand that a detailed programme in accordance with this policy has not been fully worked out. Meanwhile, work continues along the lines indicated in the recently-published "Chemistry Research, 1957."

The new laboratory at Stevenage will be called the Warren Spring Laboratory. This is intended to be a versatile station capable of tackling a wide range of subjects. Current plans include programmes on air pollution, on the synthesis of oil and chemicals from carbon monoxide and hydrogen, and on mineral processing. DR. D. D. PRATT, Director of the National Chemical Laboratory, has informed us that it is hoped pilot plant operations will be carried out at the Warren Spring Laboratory where most of the chemical engineering research will be carried out. In addition, SIR HARRY MELVILLE recently stated that the station would conduct research needed for scaling up processes.

. . . . and New Arrangements

There will also be changes in organisation. A new system has been introduced for control of research programmes at these two laboratories. Under the former system Research Boards were responsible to the Research Council, but there was not necessarily any common membership. Small Steering Committees have now been set up. It is an essential feature of the new arrangement that these are full committees of the Research Council and that there will be a direct link between the two bodies, because the Chairmen of the Committees are members of the Council.

In addition to the Chairman there will be four members of each committee. Two will be from industry and will have experience in research management. The other two members will be the Secretary of the Department of Scientific and Industrial Research and the Director of the Laboratory. The committees are empowered to set up specialist sub-committees as necessary, to advise on the different fields of research covered by the Laboratories.

Why Train Overseas Engineers?

IT is a truism that trade follows the technologist and the export of British technical knowledge now is one of the best ways of stimulating the export of British engineering equipment in the future. It is evidently for this reason that more than 180 engineering firms in London, Birmingham, Glasgow, Liverpool and other industrial centres are taking part in the Federation of British Industries Overseas Scholarship Scheme, of which the Fourth Annual Report has just been published. The scheme provides training with British engineering firms —usually for two years—for selected graduate engineers from the Commonwealth, South and Central America, the Middle East and certain countries in South-East Asia.

Great developments of natural resources and public utilities are being planned in many overseas countries. Fulfilment of these projects will depend on both the provision of capital and on the availability of properly trained engineers who are nationals of the countries. Thus this export of technical knowledge helps the countries concerned and at the same time creates international goodwill for Britain. By March 31, 1958, 228 F.B.I. Overseas Scholars from 29 different countries had come to this country; of these, 98 were still here at that date and 130 had returned home after completing their training. The first scholars from Jordan, Kuwait, Nicaragua and Salvador arrived during 1958. A particularly satisfactory part of the scheme has been the reference in reports by individual firms to the high personal qualities of the engineers in training as well as their technical abilities.

What Happens to Blasted Rock?

PROBABLY the most commonly-held concept of rock breakage by explosives is that the gases generated by the detonation of the explosive push the rock surrounding the charge toward a free surface. However, a careful study of the fracture patterns developed in plastics, metals and rocks under explosive attack has revealed that the fractures are caused by stress waves reflected from a free surface. The high gas pressure developed by the detonation of the explosive produces the stress waves, but the rock breakage is not directly caused by expansion of the gases.

In a recent paper,* J. M. HUMPHRYS, after reviewing the history of explosives development, discusses the evidence for this reflection theory. When an explosive charge is detonated in a drill hole in rock it produces gas at very high pressure and temperature which quickly fills the charge space and exerts pressures on the surrounding rock. This pressure generates a compressive stress pulse that travels radially outward in the surrounding rock with a speed equal to or greater than that of sound in the rock. Associated with the radial compressive pulse is a tangential tensile pulse. Near the explosion, the amplitude of the compressive stress pulse is greater than

the compressive strength of the rock and the rock is fractured by crushing. As the pulse travels outward its amplitude decreases rapidly. Thus the extent of the crushed zone is relatively small.

If no free surface is near the explosion, the only damage to the rock would be the crushed zone around the shot hole and some associated radial cracking. However, when a longitudinal compressive stress pulse arrives at a free surface, two reflected pulses are generated: (i) a reflected longitudinal tensile stress pulse and (ii) a reflected shear stress pulse. Because the propagation velocity of longitudinal pulses is greater than that of the shear pulses, the effects of the reflected tensile pulse are manifested first. The tensile strength of rock is only a few per cent of its strength in compression or shear, and therefore the reflected tensile pulse is able to break rock in tension as it moves back into the solid rock. The crack developed by this tensile failure will act as a new free surface from which the impinging tail of the compressive pulse will be reflected as a new tensile pulse. In this way the rock forms a number of slabs progressively from the free surface toward the explosive charge location.

* *Chemistry in Canada* June, 1958, p.60.

Crystallisation of Dendrites from Aqueous Solutions

IS it possible to obtain useful information about the crystallisation of metallic melts from studies of aqueous solutions? An interesting contribution to this subject has been made by V. KOSELEV in *Hutnické Listy*, No. 4, 1958, p. 299. A highly versatile catalyst for transforming a normal mode of crystallisation from aqueous solution into a dendritic form was found to be ordinary gelatine. This effected dendritic crystallisation of potassium permanganate, potassium dichromate and several other materials. In the case of $Cu(NH_3)_4Cl$ the desired change was brought about by addition of ammonia solution.

The most interesting of these experiments were those with NaCl because its atoms are arranged identically with the atoms of gamma iron. ING. KOSELEV therefore undertook a detailed study of the formation of its crystals. He found that the first sign of the formation of dendrites is the formation of a chain of crystals in place of a simple normal crystal growing in the axial direction. In the next stage formation of branches takes place but the faces in the direction of growth still remain smooth. As the dendritic process approaches its maximum the ends of the crystals become more pointed. KOSELEV states that the Russian Worker KUZNETZOV explains the growth of the points by the presence of impurities insoluble in the crystal. According to this theory the concentration of impurities in the neighbourhood of a point is lower than elsewhere so that the growth of the crystal is least obstructed there. Conversely the highest concentration occurs near the corners, resulting in a considerable curtailment of the growing process.

Speeding-up Process Evaluation

"SCI-FIC come to life" is one's first impression on reading about the miniature pilot plant being built by Consolidated Electrodynamics for Esso. The automatic miniature plant will be compact enough to fit into a small air-conditioned laboratory. It will be applied to power-forming, hydrofining and catalyst aging evaluation. Designed for automatic leak test, reactor and catalyst regeneration, the highly instrumented model contains a modular plant graphic panel, electronic control, continuous analysers, logging and scanning equipment and a digital computer.

After the introduction of a previously prepared catalyst into the reactor section, an automatic programme system will take over and conduct an entire catalyst evaluation programme. If a condition outside a pre-set limit is detected, the unit will automatically close down. An engineer feeds in initial instructions, and the desk-sized computer automatically conducts round-the-clock tests, some lasting for weeks, constantly analysing raw materials and products. Information on temperatures, pressures, flow rates, and chemical composition, plus other variables, is fed automatically into the computer several times a second. The computer digests the data and presents it in a final form and resets the plant operational programme.

All this is a logical development of present trends though it seems only a short step removed from the modern style of horror film based on the machine taking over from the mad scientist more than the latter had intended.

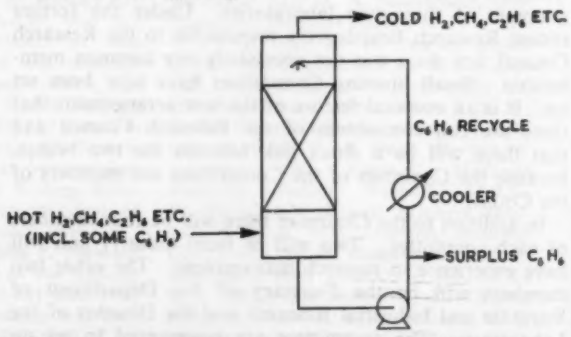
Lifting and Carrying

EVERY year in industry nearly 50,000 accidents caused in the handling and carrying of goods are reported to H.M. Inspectors of Factories. Men, women, boys and girls, employed in almost every trade, are involved. Chemical industries are not listed as major contributors to this unfortunate record but they may still find it useful to have available the first* of a new series of booklets issued by the Ministry of Labour and National Service. There is also an accompanying coloured wall-sheet, size 20 in. x 30 in., illustrating the "rights" and "wrongs" of lifting and carrying. The booklets are not intended only for the information of management. It is hoped that some of them will be found suitable for a wider circulation amongst workers at all levels. Essence of the message is that lifting should rely on skilful use of the right muscles and not on brute force. The language is simple and direct; the frequent illustrations are clear.

* Safety, Health and Welfare, New Series No. 1. Lifting and Carrying. H.M.S.O. 1s.

How Do You Design a Direct Contact Cooler?

WE do not normally run a "readers' enquiry" column but we are often able to match up engineers with problems and those with solutions. One case that has escaped us so far is finding the wise man who can deal with the following design:—



In such a case, how can the size of the direct contact cooling tower be calculated for a given packing and terminal conditions?

Recommended Methods for Analysis of Trade Effluents

THE Association of British Chemical Manufacturers is recommending its members to analyse regularly the trade effluents discharged to rivers or sewers. This development was disclosed by MR. N. F. PATTERSON, O.B.E., chairman of the A.B.C.M. Trade Effluents Committee, at a luncheon held to launch a new book on recommended analytical methods.* In an address on the same occasion DR. A. KEY, Senior Chemical Inspector of the Ministry of Housing, welcomed the new publication. Referring to the Ministry's own publication on analysis of sewage, DR. KEY said that he did not regard the two books as rivals. Trade effluents can contain almost anything but fortunately no one of them contains everything. Sewage can also contain anything and it is probably true to say that some sewages do contain everything, but fortunately many constituents are present in such small concentrations as to make it unnecessary to determine or estimate them all. Such differences clearly exist as to make methods of analysis best applicable to one not always the most suitable for the other. It was therefore easy to justify separate publications dealing with the two types of liquid.

And the final comment of the Senior Chemical Inspector deserves quoting verbatim: "What you are saying to Industry—and others—is this 'If you wish to analyse trade effluents, here are a number of tests which we have considered and tried out under a variety of conditions. We think they are reliable, that they give the right results and they are as simple as is consistent with that. We therefore recommend them.' I think that is the right approach."

* Recommended Methods for Analysis of Trade Effluents. 42s. Society for Analytical Chemistry, 1958.

Atomic Energy: Annual Report

PUBLIC interest in atomic energy naturally centres mainly around the nuclear reactors and the possibilities of thermonuclear energy. Yet behind all this work is an extensive programme of chemical and allied processing. In the recently published 4th Annual Report of the Atomic Energy Authority, there are several references to this difficult field of work often with dangerously active materials. A plant for producing highly enriched uranium metal from uranium tetrafluoride is said to have operated satisfactorily, and a large variety of residues containing enriched uranium has been processed. In one unit of the uranium purification plant, a purification process for the uranium stream from the primary separation plant, using tributyl phosphate as solvent, has been tested. The object is to increase the decontamination factor from residual fission products. An experimental caesium extraction plant has operated throughout the year and eight sources totalling about 9500 curies of caesium have been despatched. The prototype is difficult to operate, but it is providing valuable experiences for the design of a large scale plant.

At the Wantage Radiation Laboratory, 11 irradiation cells were in use and Cobalt-60 sources with strengths from 200 to 4500 curies. Initial work in the field of industrial chemistry has been on polymerisation and short notes on this work are also reported.

Catching them Young

ACCOMPANYING the Roumanian journal *Revista de Chimie* is a small booklet well illustrated with technical diagrams and attractively laid out. The supplement enclosed with the May issue, for example, deals with "safety valves" and includes under that heading calculations of the diameter required for a steam valve. This is worked out in detail including all the arithmetic. Another article deals with calculation of dimensions of pipes for air and gases. These two articles are followed by "Technical Hints" such as how to deal with blocking of condensers when distilling phenols, fatty acids and other products. Under the heading "Labor" are instructions on how to make up universal indicator and recipes for making-up constant-temperature bath liquids, and cooling mixtures. A questionnaire follows. "The author of the theory of . . . in organic chemistry is A. M. BUTLEROV; The general formula of paraffin hydrocarbons is . . .?" The answers to questions in the previous number are given as well as a cartoon entitled "The Adventures of Amalgam." A chemical crossword puzzle and a drawing for the "distracted draughtsman" complete the issue. We understand that Deutsche Farben-Zeitschrift issue something similar called "Blätter für den Nachwuchs," but we have come across nothing exactly like this in English. For schoolboys and girls, the brightly-produced "Science Club"* should help to provoke, and partly satisfy, a wide interest in science. Specifically for embryo chemical engineers, however, we know of nothing.

* Published by Junior Club Publications Ltd., W.C.1. Twice a term.

Fertiliser Subsidy

IN our issue of June, 1958, page 301, we quoted verbatim some information supplied to us by the Ministry of Agriculture, Fisheries and Food. This included tables giving the deliveries in the United Kingdom of fertilisers in terms of nitrogen, phosphate and potash content, and a statement that "to encourage the greater use of fertilisers the Government pay contributions to farmers towards the cost of fertilisers purchased." It has been pointed out to us by Propane Fertilisers Ltd. that there is no Government subsidy on potash. The information supplied might be taken to imply that the three fertiliser constituents mentioned are equally likely to justify contributions towards the cost of the fertiliser.

A spokesman of the Ministry has now confirmed that contributions are paid only on inorganic nitrogenous and phosphatic fertilisers. Contributions are also paid on compound fertilisers containing potash but only by virtue of their content of nitrogen and phosphate. The question of subsidy for potash fertilisers has often been considered but rejected. All our supplies of potash are imported whereas for nitrogen and phosphates the supply situation is rather different.

Oscillating Conveyors

FOR conveying solids or semi-solids at moderate rates of flow, oscillating conveyors are said to offer many attractions. They are used extensively in agriculture and increasingly in chemical manufacture. A "brief interim account" of research on the exact mode of operation of this form of conveyor has now been published by P. E. BERRY.* The practical work was carried out on a conveyor about 27 ft. long consisting of an aluminium box-section girder with means provided for attaching 9 in. wide troughs. It followed a theoretical analysis of the motion of a rigid particle on an oscillating conveyor. Mr. Berry points out that the latter can be defined as a trough

or platform which oscillates sinusoidally in a direction lying in the vertical plane containing the longitudinal axis of the trough and at some mean angle θ to the vertical. It is completely specified by

(i) The angle θ (the "link angle") to the vertical;
(ii) The amplitude of oscillation (approximately the crank throw);
(iii) The frequency of oscillation.

Further development of the programme will also include a study of the dynamics of the substances conveyed. The author suggests that if more can be learnt about the trough side-wall forces it may be possible greatly to increase the flow along the conveyor trough.

* *J. Agric. Eng. Res.*, Vol. 3, No. 3, 1958, p.249.

Trends in the Petroleum Industry

DATA on the shift of world oil operations away from the U.S.A. are quoted in the current Chairman's Report on the work of the Council of British Manufacturers of Petroleum Equipment. The Middle East is now clearly the new "centre of gravity" of the world's oil reserves while, in refining capacity, the U.S.A. proportion is falling away. In 1935 the U.S.A. did 72% of the world's refining of crude oil. Today the proportion is 52%. This trend is also true of consumption. The U.S.A. used 68% of the world's total oil products in 1946; the figure has now fallen to 54%. This situation arises from the fact that consumption is rising in many areas abroad faster than in the U.S.A. A further important feature is the gain of six shillings per ton, or 21% for 45,000 ton tankers, for crude oil supplied to the U.K. compared with the cost of supply to the East Coast of the U.S.A.

From these favourable circumstances, MR. T. L. BONSTOW, the consultant to the Council, drew these happy conclusions. The refining of crude petroleum in the United Kingdom by American as well as British oil companies should prosper so long as the crude material remains available from the Middle East. With this should flourish many other industries by provision of hydrocarbons—notably, the petro-chemical, chemical, plastics, solvent, soap, paints, and synthetic textiles industries.

Safe Use of Industrial Beta-Ray Sources

STRANGELY archaic-looking type-face has been used by the National Bureau of Standards in presenting an up-to-date brochure of information entitled "Safe Design and Use of Industrial Beta-Ray Sources" (20c). After discussing the range and nature of the hazards, the brochure reviews selection, design, manufacture, installation and use of these sealed sources. Maintenance and disposal problems also receive attention. The information is naturally based on the radiation protection regulations of the U.S. Atomic Energy Commission and other Federal and State agencies. When installing a source, users are recommended to set up an adequate safety programme including the provision of an instruction manual. The only comparable recent British publication is, we understand, the Preliminary Draft of the Factories (Ionising Radiations) Special Regulations. This is wider in scope—as its title indicates—but far less detailed in treatment.

Who Does What and Where?

RESEARCH at the universities accounts for only a small part of the national expenditure on research. Yet it is of key value in the advancement of knowledge leading to technological improvements. D.S.I.R. have again published an indexed volume of brief notes on the scientific research in progress at British universities and university colleges. It describes the nature of the projects in sufficient detail to indicate the scope of the research work done by the science departments and individual teams of investigators. Engineering, chemical, at four institutions is listed in the index but Manchester seems to have escaped mention and Sheffield's Department of Fuel Technology and Chemical Engineering is listed only under Fuels. At the Royal College of Science and Technology, Glasgow, where chemical engineering forms a part of a composite department of engineering, neither the general name of the department nor its constituent parts were found in the index. There are other oddities. Take the item which appears under the following sequence of sub-headings as part of the work at Glasgow—"Engineering. Mechanical, Civil and Chemical. Fluids: Transportation of solids by fluids." This item cannot be found indexed under any of the key words in the above quotation. But the most important omission of course is the lack of reference to research at technical colleges—which is often at "University level" and leads to the award of higher degrees. Correcting this would involve a change of policy and title. We understand that such a change is being considered.

This is almost a very useful book.

"Scientific Research in British Universities" 1957-58. H.M.S.O. £1 2s. 6d.

Studies in Two-Phase Air-Water Flow

THE density of an air-water mixture changes during expansion or contraction as it flows through a pipe. An equation for the void volume fraction of the air, α, has now been put forward* by M. PETRICK of the Argonne National Laboratory, Illinois.

$$\alpha_2 = \frac{1}{\dfrac{\dfrac{P_2}{P_1}\left(\dfrac{1}{\alpha_1}\right)}{\left(\dfrac{A_1}{A_2}\right)^{0.2}} + 1}$$

In this expression P is the pressure in psi absolute and the suffixes refer to successive positions. In the same report expressions have been proposed for the relative velocity of a two-phase (air-water) fluid as a function of water velocity and the mixture quality, and for the length of the transition zone following an expansion as a function of quality, mass-flow rate and the area ratio. DR. PETRICK also found that the distribution of the air phase in the water phase was parabolic in nature, but the ratio of $\alpha_{maximum}/\alpha_{average}$ which characterises the distribution varied at random. A further part of this work was concerned with the two-phase pressure drop.

* Report ANL—5787.

A 24-page reprint of a series of articles entitled "Liquid Atomisation in Chemical Engineering" by R. P. Fraser, O.B.E., M.I. Chem. E., P. Eisenklam, Ph.D., M.Eng.Sc., A.M.I.Chem.E., and N. Dombrowski, Ph.D., A.M.I.Chem.E., published in *British Chemical Engineering*, has been specially prepared in response to numerous requests. Copies are available from the Publishers at 4s. each postage 2d. The appropriate remittance must accompany orders, which should be sent to The Circulation Manager, *British Chemical Engineering*, Drury House, Russell Street, London, W.C.2.

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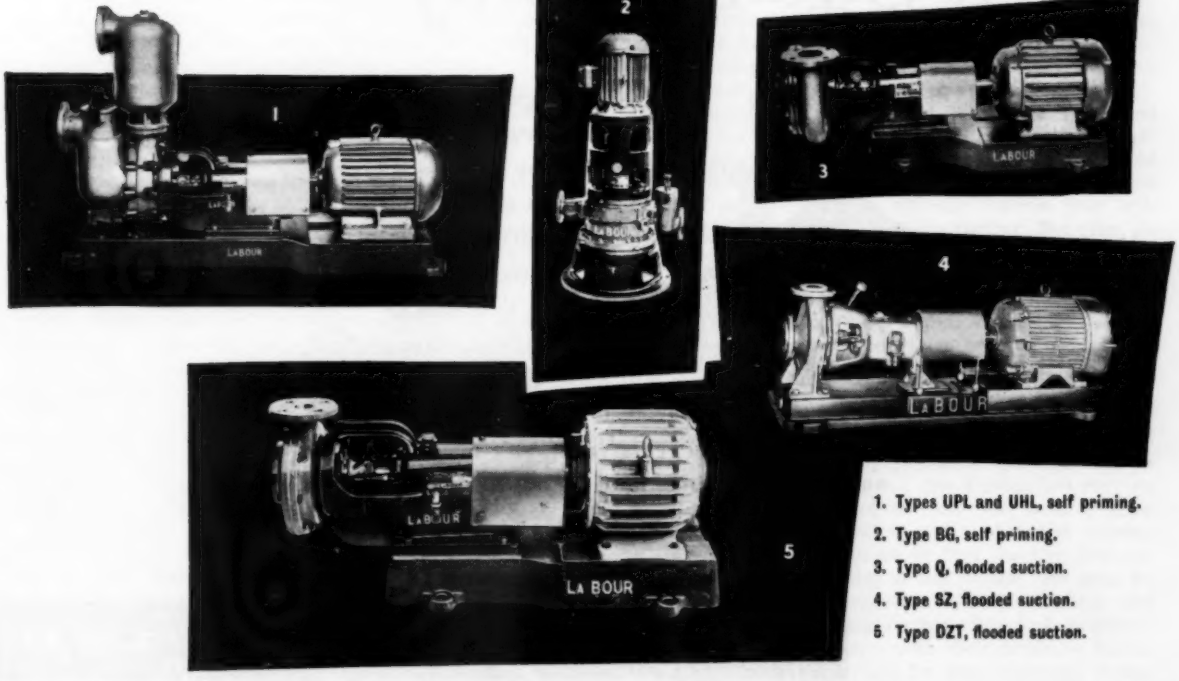

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A HEYWOOD PUBLICATION
British Chemical Engineering

Olympian Reflections

PREOCCUPATION with the sensational may have underlaid the failure of the daily Press to tell its readers about the recent Olympia Exhibition and to encourage them to view a cultured demonstration of engineering skill. From those who can look no farther than automobiles for exportable engineering goods, it would have been optimistic to expect mention of some of the problems affecting the export of the products of the chemical plant industry. Even the presence of eminence from the Atomic Energy Authority, whose achievements in the past Fleet Street has greeted with unmeasured enthusiasm, failed to gain mention.

It was in the nature of things that the Symposium which was run in conjunction with the Exhibition should bring to the surface a number of important problems—some of them hitherto subjects of private conversation. One of these is that U.S. contractors are often preferred to British contractors mainly because their constructional costs are lower than ours; but the dismal phenomenon to which SIR HUGH BEAVER referred to at the conclusion of one of the sessions came as a salutary shock. We would not have expected in this age when in all other realms of engineering the art of craftsmanship has been forsaken for the path of good sound engineering practices, to find that construction costs were steadily out-distancing plant costs. This, indeed, was a blow and it was described justifiably as a canker in the nation's enterprise.

To comprehend why the costs of American contractors are lower than those of their British counterparts might be a profitable exercise, and whether we in this country make the best use of modern methods of construction and contract execution is open to some doubt; yet it is obvious in this highly competitive field, aggravated by ever-rising costs and with the European Free Trade Area ahead, that a serious study as a prelude to action is a national necessity. It may be that fuller use could be made of cost studies and cost analysis—those prime necessities of any serious construction operation without which our ideas of cost-per-ton erected are likely to be uselessly vague and may remain undetected the coexistence of productive and unproductive methods of construction.

Whether the lines of improvement should follow the more efficient use of manpower and supervision of modern construction equipment and of better planning aided by models, or whether more radical measures are demanded, might be profitably discussed at a future symposium.

Imponderables, of course, abound in constructional work; the supply of materials for one thing is uncertain and so is the weather. Nevertheless, the existence of imponderables does not explain the changing cost relation to which the President of the Institution drew our attention, and its root cause needs urgently to be disclosed. Mind-changing in the later stages of a project—another source of spiralling construction costs—might also come under review, although there are here obvious difficulties. It would also be worth knowing how far the scheduling of design work in conditions of designer shortage contributes to embarrassing revisions in design; again, the consequences of having recourse, through urgency of the project or gaps in our knowledge, to short-cut methods, whose underlying assumptions were unrecognised at the time, might well be enlarged upon.

Another problem of prime importance to chemical and petroleum engineering contractors which came to light concerned the difficulties which faced this country in selling projects abroad. In some markets there would be an offer of a complete plant from one of the East European countries combined with a low-interest, long-term credit. On the other hand the offer might come from a U.S. undertaking supported by an offer of credit from the Import-Export Bank. This country, however, with all its undoubted resources, is unable to integrate them to the degree necessary to bring a large multi-process project into operation. There is the oft-recurring difficulty that the process data for design work are often not possessed by the would-be buyer; and if this country is to hold its own in the face of foreign competition, then it is necessary to mobilise for a project resources much greater than can be found within a single contracting organisation. These problems are acute, and other than some form of co-operative organisation in which consultants might play a very useful part, it is difficult to see any real solution.

At the Symposium a great deal of argument revolved around the desirable qualities which the project engineer should possess and if there was agreement that he should be a high-level person with many virtues—though one contributor suggested that a versatile barrow boy with drive might do—agreement went no further. But after all that has been said in the past about the chemical engineer as a co-ordinator, it was strange to find a strong preference for the mechanical engineer, albeit with a flavouring of chemical engineering to fill the leading role.

The shortage of chemical engineers, and the need, therefore, to concentrate them in the province of design alone, may be a possible reason for this peculiarity which might in time be remedied when the supply improved. If this is so, it may indeed mean a long wait before the chemical engineers occupy the leading positions that many of us believe they should occupy; but this explanation may be no more than a fragment of the real one, since it is by results that boards of directors are guided and appearances may lead them to conclude that the chemical engineer is not their man. May it not be the case that we do not produce enough engineers with the outlook and sense of urgency that the engineering of projects requires? Are there too many engineers with their heads so full of parameters that their capacities for leadership and practical creativity have been stifled?

66.048.375

ENTRAINMENT FROM BUBBLE-CAP DISTILLATION PLATES

The causes of entrainment are discussed and a method of designing bubble-cap plates is given which takes into account entrainment

by H. E. EDULJEE, Ph.D., A.M.I.Chem.E.

IN recent years much work has been done on the behaviour of bubble-cap distillation plates in order to put the design of these plates on a rational basis. The optimum design for a particular vapour loading often requires a knowledge of the entrainment from a plate; yet this aspect of plate design is probably the least satisfactorily correlated. The equations of SOUDERS and BROWN[17] and ELD[6] give maximum vapour velocities and minimum plate spacing compatible with satisfactory products, but these equations do not indicate the extent of entrainment. Two attempts [5, 16] have been made to correlate entrainment data in the form of equations that would allow the amount of entrainment to be calculated, but again the properties of the liquid have not been fully allowed for.

Entrainment may be expected to be influenced by vapour velocity, plate spacing, design of bubble-cap, physical properties of the vapour and the liquid. While the first two factors have been well studied by all workers, no one has systematically studied all the factors together. It was felt worth while, however, to study critically the published data and try to arrive at a correlation that would include all the above factors.

The published data of ATTERIDG *et al.*,[1] HOLBROOK and BAKER,[7] JONES and PYLE,[9] PYOTT *et al.*,[13] SHERWOOD and JENNY[15] and STRANG[18] were used for this study; SIMKIN *et al.*[16] have not, unfortunately, published the data of their extensive and careful work. For details of the trays and caps, the original references may be consulted.

Effect of Plate Spacing

Previous correlations had correlated logarithm of entrainment (E) as a linear function of $1/T$, where T is the plate-spacing. Some trial plots of log E—where E is entrainment, expressed as lb. liquid per hour per sq. ft of free plate area—against log T gave slopes ranging from -2.66 to -3.06. The correct distance to consider is not the distance from a plate to the one above, but the distance from the top of the frothing mass of liquid to the plate above, i.e., the clear distances, S, the liquid drops travel is the plate-spacing minus froth height. HUNT *et al.*[8] have used the same concept of clear space in their study of entrainment from perforated plates. GILLILAND[14] has suggested that, for estimating the liquid gradient on a bubble-cap plate, the froth height should be taken as twice the hydrostatic head of the clear liquid at the outflow weir; the hydrostatic head is given by weir height plus weir crest. It is obviously desirable that a factor that effects two or three phenomena on a plate should be defined in a similar manner for all cases, so GILLILAND's estimate of froth height was accepted to apply to entrainment also—with one slight difference: for simplicity, froth height is defined for entrainment as being equal to twice the weir height.

There is some justification for estimating froth height as twice the weir height. STRANG[18] has actually measured the froth height on a plate with 2.3 in. weir and got values ranging from 4.0 to 5.0 in.; the suggested estimate of froth height would be 4.6 in. The relationship can also be derived approximately. The aeration factor, β, is defined as

$$\beta = \frac{\triangle p_a - \triangle p_b}{\rho\,(h_a - h_b)}$$

where ρ = specific gravity of clear liquid;
$\triangle p$ = pressure drop;
h = height of clear liquid; and
a, b are two positions of the clear liquid height.

$\triangle p$ can also be expressed in terms of the weight of the froth per unit area:

$$\beta = \frac{\rho^*\,(f_a - f_b)}{\rho\,(h_a - h_b)}$$

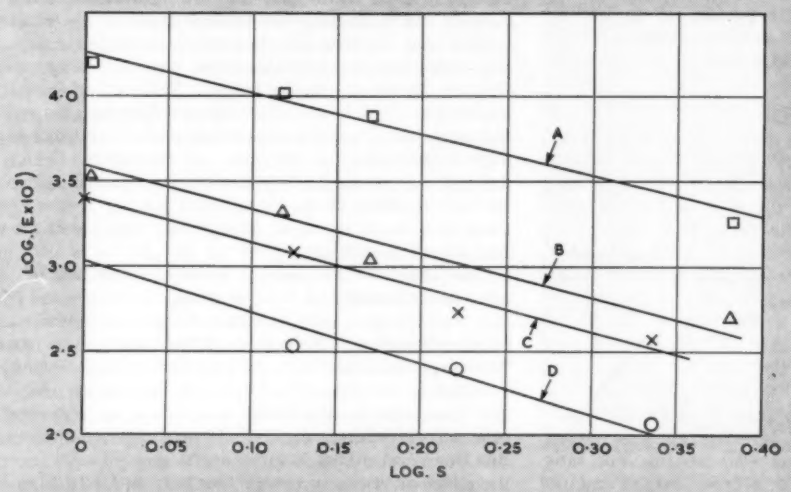
where ρ^* = specific gravity of froth; and
f = froth height.

Symbols Used

E = entrainment, lb. liquid/(hr) (sq. ft free area of plate);
E^* = entrainment corrected for liquid properties and plate spacing;
S = clear height, ft, given by plate-spacing — foam height;
T = plate-spacing, ft;
v = vapour velocity, ft/sec., based on free area of plate;
σ = surface tension of liquid, dynes/cm;
μ = viscosity of liquid, centipoises;
ρ_L = density of liquid, lb./cu. ft;
ρ_V = density of vapour, lb./cu. ft; and
$\triangle\rho = (\rho_L - \rho_V)$.

Dr. Eduljee *is with National Peroxide Ltd., Sewree Cross Road, Bombay-31, India.*

Fig. 1. Effect of clear height—plate spacing minus foam height—S ft on entrainment **E** *lb. liquid/(hr) (sq. ft).*



CURVE	SYSTEM	v, FT./SEC.	REF.
A	STEAM-BRINE	6·0	(7)
B	STEAM-BRINE	4·3	(7)
C	AIR-KEROSENE	1·75	(13)
D	AIR-KEROSENE	1·25	(13)

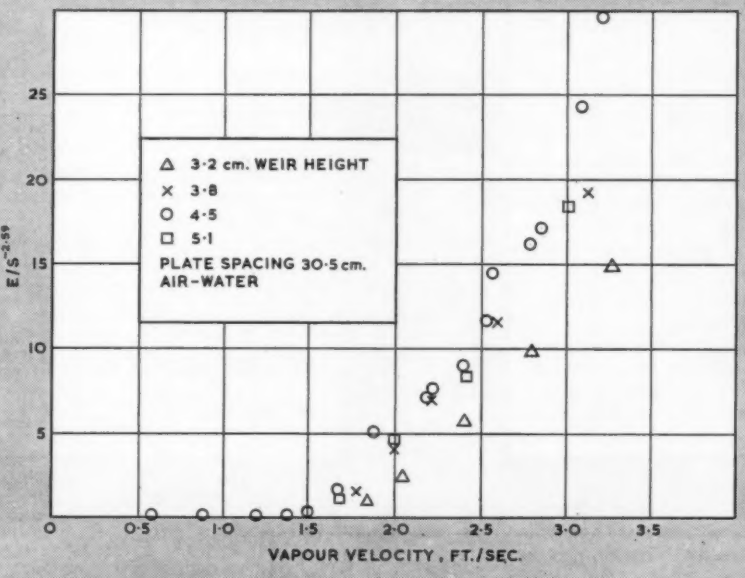


Fig. 2. Correlation of effect of static submergence on entrainment. (Data of Sherwood and Jenny.[15]*)*

β varies little for different liquids and its value is between 0.75 and 0.80; ρ^*/ρ is about 0.33 to 0.4 for normal plate conditions, so:

$$(f_a - f_b) \simeq 2(h_a - h_b)$$

when $h_b = 0$, then $f_b = 0$ *and* $f_a \simeq 2h_a$

In Fig. 1 some typical plots of log E against log S are shown for constant values of vapour velocity through the column. The lines are practically parallel to each other and the average of 15 such plots gave the slope as -2.59, with extreme values of -2.50 and -2.68.

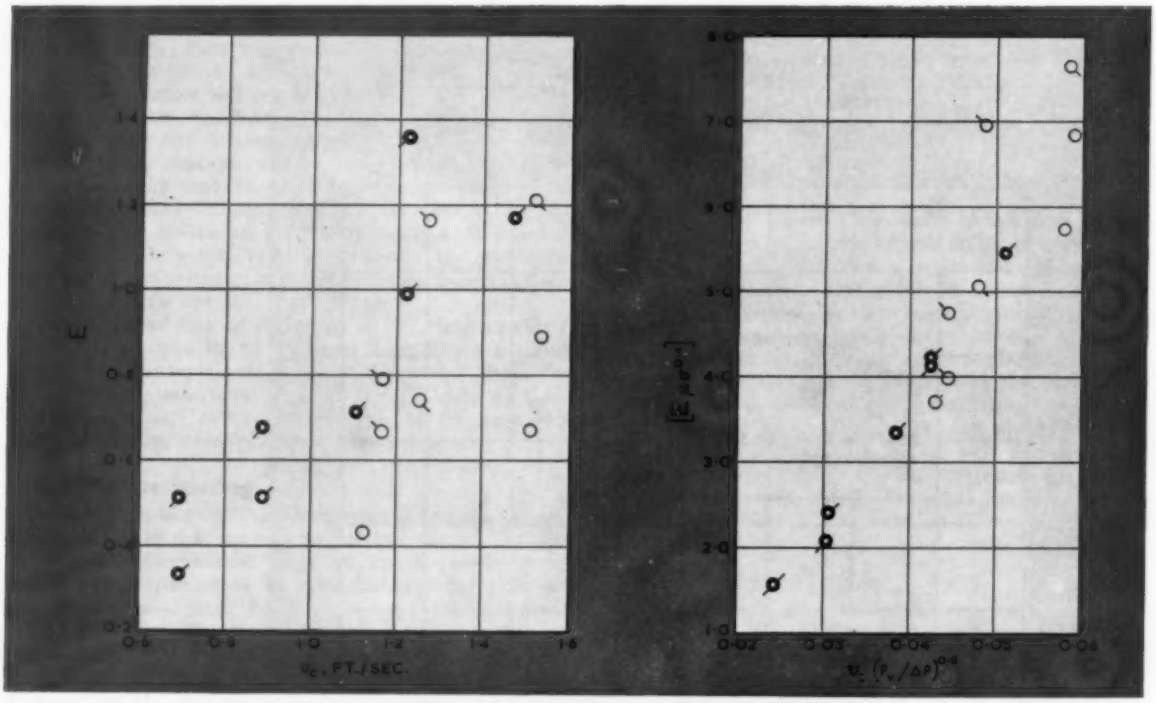
Effect of Static Submergence

SHERWOOD and JENNY[15] have shown that entrainment increases with static submergence. The static submergence can be varied by altering the weir height or by altering the height of the slot. Altering the weir height will alter the froth height and therefore the value of S; altering the slot height will not affect the value of S. If the correlation between E and S also accounts for the effect of static submergence, then it shows that height of slot has no effect on entrainment. In Fig. 2 the data of SHERWOOD and JENNY[15] have been plotted as $E/S^{-2.59}$ against vapour velocity for four weir heights; the data for three of the heights correlate well. In the case of the weir height of 3.2 cm the static submergence is only 0.2 in. and it would be difficult to get entrainment data which would be in concordance with data for greater weir heights. The satisfactory correlation shows that it is froth height and not static submergence which is important in causing entrainment.

Effect of Vapour and Liquid Properties

When vapour issues from a slot with velocity, part of the energy it possesses is used to break up the liquid into drops. It may therefore be expected that the greater the viscosity of the liquid, the lesser will be the entrainment because the viscosity will damp the transfer of energy from vapour to liquid. Furthermore, the greater the surface tension of the liquid, the more entrainment one may expect; this is because the greater the surface tension the greater the internal pressure required to burst a bubble, and hence when the bubble does burst the fragments are thrown up to a greater height. This is in accord with experience with evaporator tubes.[11] The height to which the drops of liquid will be carried will depend, for a given vapour velocity, on the size of the drops (which will depend on the surface tension of the liquids) and on the specific gravities of the liquid and vapour. Thus, entrainment will be a function of μ, σ, ρ_V and ρ_L, the vapour and liquid densities.

The effect of ρ_V and ρ_L have been shown[16, 17] to be adequately correlated by the group $[\rho_V/(\rho_L - \rho_V)]^{0.5}$ and this group is generally accepted. Such data as exist on the effect of surface tension on entrainment show that entrainment increases with decrease of surface tension. This is contrary to expectation and the inadequate data make any discussion on this point impossible. An empirical correlation of existing data is all that can be attempted at this stage and it was found that the group $[\mu\sigma^{0.4}]$ correlated the effect of viscosity and surface tension fairly adequately; this is shown in Fig. 3 where the data of PYOTT *et al.*[13] are shown before and after correction for liquid properties.



SYMBOL	LIQUID	μ	σ	ρ_L
○	KEROSENE (80°F)	2·20	31·6	50·8
◎	KEROSENE (100°F)	1·75	30·3	50·8
◔	KEROSENE (120°F)	1·55	29·4	50·8
◉	WATER (100°F)	0·85	71·8	62·3
●	WATER (120°F)	0·56	68·1	62·3

Fig. 3a (left). Plot of entrainment against vapour velocity based on data by Pyott et al.[13] *This chart is uncorrected for liquid properties. Gas air; plate spacing: 20 in.*
Fig. 3b (right). This graph shows the data of Fig. 3a corrected for liquid properties.

Effect of Vapour Velocity

A plot of entrainment versus vapour velocity (Fig. 4) shows that at low vapour velocity the entrainment is very small and does not increase much with increase in velocity. Beyond a certain "critical" velocity the entrainment increases rapidly and continuously with increase in vapour velocity. At the points marked *A* in Fig. 4 the entrainment is of the order of 0.02-0.4 lb. of liquid/100 lb. vapour. This amount of entrainment will have no perceptible effect on the plate efficiency. Even in the case where entrainment is likely to affect the taste or colour of the product, if the product is removed as vapour then sufficient height can be given above the top plate to cut down the entrainment. The steeply rising parts of the curves in Fig. 6 are the only ones of interest in distillation and the correlation will be confined to these parts.

If the energy of the vapour leaving the slots is used to break up the liquid into drops, then the vapour velocity through the slots may be an important factor; the height to which the drops will be carried will depend on the vapour velocity through the column. We thus have to consider both slot velocities and column velocities.

SHERWOOD and JENNY[15] have studied one design of cap but in various combinations of number-of-caps and column diameter, thus varying the ratio slot area/column area from 10.6% to 4.9%; for the same column velocity, we should therefore get different slot velocities for the various combinations. The SHERWOOD-JENNY data are shown in Fig. 5 as a plot of Log E against v and no particular trend can be noticed between the positions of the points and the slot area/column area ratio.

From Fig. 5 we may therefore conclude that in the range of vapour velocities of interest in ordinary distillation, slot velocity has a minor effect and we need consider only the column velocity. It also shows that as far as conventional bubble-caps are concerned, cap design has little or no influence on entrainment. Although SIMPKIN *et al.*[16] also assert this, their correlating equation includes a term for slot opening and hence the influence of cap design on entrainment is implied in their work.

The Final Correlation

The final correlation of entrainment data is shown in Fig. 6, where log E^* is plotted against $v(\rho_V/\triangle\rho)^{0.5}$. E^* is given by

$$E^* = [E \,.\, S^{2.59} \;\; \mu\sigma^{0.4}] \qquad \ldots . (1)$$

The plot includes representative data of all the investigators. ATTERIDG *et al.*[1] have worked with tunnel-type caps and their data show certain pecularities at liquid velocities corresponding to a weir crest of about 1.75 in.; in Fig. 6, data for 100 gph and 500 gph liquid rates are plotted. HOLBROOK and BAKER'S[7] original data show severe scattering even for duplicate runs; when the averages of these duplicate runs are plotted, as in Fig. 6, rather than the individual value of each run, then the scattering is considerably less.

To facilitate the use of Fig. 6, the co-ordinates of the plot are listed in Table I.

Discussion

The average per cent deviation of the calculated values of entrainment from the experimental values are as follows:

ATTERIDG,[1] 17%; HOLBROOK and BAKER,[7] 31%; JONES and PYLE,[9] 23.5%; PYOTT *et al.*,[13] 17%; SHERWOOD and JENNY,[15] 11.5%; STRANG,[18] 21%. In view of the scatter of most of the original data, this agreement is perhaps the best that can be expected; it is of the same order as that claimed by SIMKIN *et al.*[16] for their equation.

The accuracy of a correlation must, however, be judged

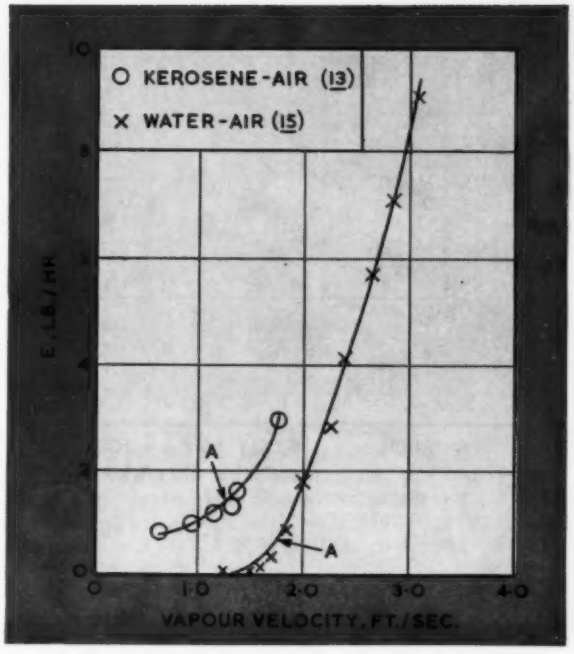
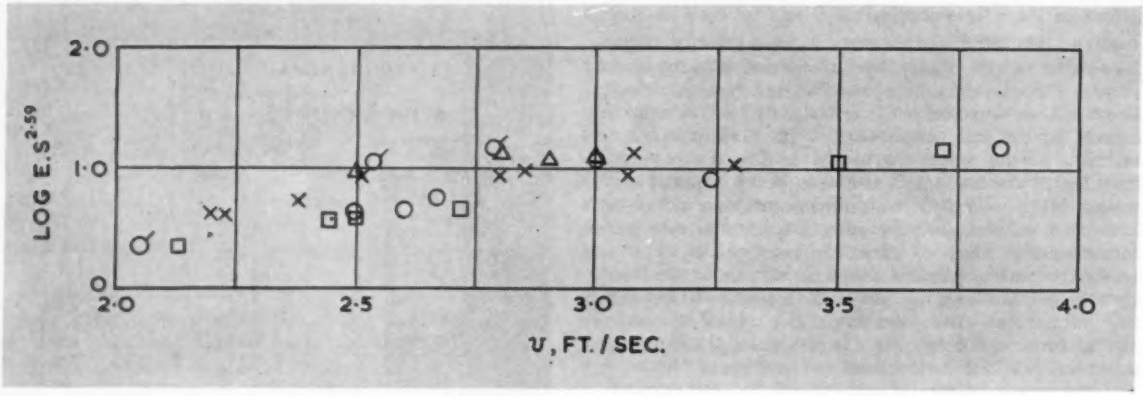


Fig. 4. Effect of vapour velocity in column on entrainment.

by the use to which the correlation is to be put. Hitherto the emphasis on entrainment has been on its effect on plate efficiency. COLBURN[2] has given an equation which allows one to calculate the effect of entrainment on efficiency. From this equation, it can be shown that for a plate with an efficiency of 80% without entrainment and O/D = 4, an entrainment of 10 mols of liquid per 100 mols of vapour will reduce the efficiency to 73%. The fall in efficiency is less than 10%. This fall is within the design limits of a tower, while 10% entrainment is considerable. Suppose a plate, as designed, was expected to show 80% efficiency, but actually it showed less and it was suspected that entrainment was the cause of this. If the actual entrainment was 10%, the efficiency of the plate would be 73%. If by means of the present or other correlations it was calculated that the entrainment was 5%, then the efficiency would be calculated to be 76%; while if the entrainment had been calculated to be 15%, the efficiency would work out to 70%. When it is recalled that it is not possible to determine, or predict, the efficiency of operating towers to within 10%, and that even a 50% error in the prediction of entrainment gives variations of efficiency within 10%, it is clear that any attempt to correlate the efficiency with entrainment will be of little value.

It may be asked: what is the value of such correlations if the predicted values of entrainment cannot be used to analyse the performance of operating towers? It is suggested here that the correlation is most useful at the *design* stage.

The conventional method of designing towers, as described in text-books,[12] is to assume a plate spacing and then calculate the vapour velocity on the basis of the SOUDERS-BROWN method,[17] which purports to give a velocity compatible with good performance. It is implied in the SOUDERS-BROWN method that the "good performance" is due to the entrainment being kept small. This method of tower design has two faults: (a) it exaggerates the importance of entrainment; and (b) it does not take into account the effect of vapour velocity *per se* on plate efficiency.



SYMBOL	SLOT AREA x 100 / COLUMN AREA
X	10·6
□	10·0
○	7·7
◎	6·1
△	4·9

Fig. 5. Plot of slot velocity against entrainment based on data of Sherwood and Jenny.[15] This figure shows that the slot velocity has little effect upon entrainment.

A rational method of design would be to first calculate a vapour velocity which would give the highest efficiency and then calculate the plate-spacing which will give a predetermined amount of entrainment at that velocity. This method has the advantage that even if the actual entrainment was 50% more or less than the design figure, its influence on efficiency would be small; hence, the correlation is used to calculate plate spacing for known entrainment. A comparison of calculated values of plate spacing with the actual spacings used shows that the average per cent deviation is 5.8. The method is illustrated by the following example.

Worked Example

Given the following data, it is desired to design a column to fractionate an ethanol-water mixture.

Feed composition $x_F = 0.25$ mols ethanol per mol of solution

Distillate $x_D = 0.80$
Bottoms $x_W = 0.05$
Reflux ratio $O/D = 3.0$
Efficiency without entrainment = 75%
Feed rate = 300 lb. mols/hr

Solution

From a material balance:

$D = 80$ lb. mols/hr
$W = 220$ „
$V = 320$ „

Since the molar latent heats are nearly equal, the McCabe-Thiele method can be used.

As the properties of the liquid and vapour streams at the top and bottom of the column are usually different, calculations should be carried out for typical plates in both sections of the column. In this example, a typical plate in the rectifying section will be designed.

Taking a plate on which the liquid has the composition of $x = 0.6$ as typical, we find from the McCabe-Thiele diagram (corrected for 75% efficiency) that the compositions of the vapours entering and leaving the plates are 0.65 and 0.67. The average density of the vapour is 0.08 lb./cu. ft, of the liquid, 49.75 lb./cu. ft, and mol wt is 34.8.

Number of Caps per Plate

Total volume of vapour entering the plate
= 147,900 cu. ft/hr = 41.2 cu. ft/sec.

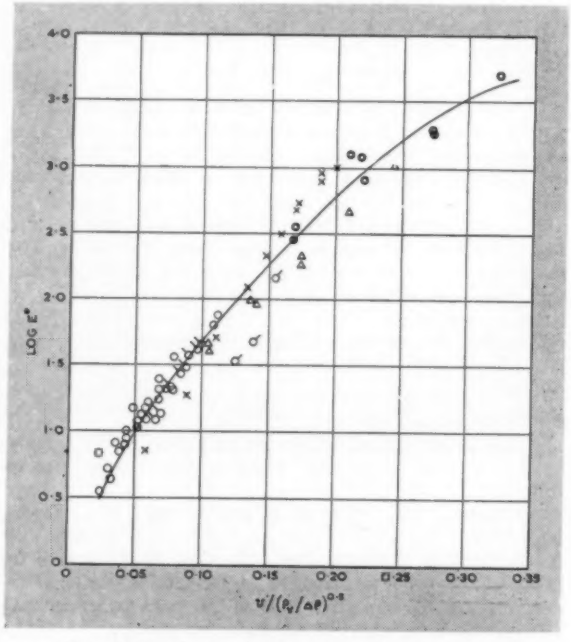


Fig. 6. Final correlation of entrainment data.

SYMBOL	AUTHOR(S)
⊙	PYOTT et. al.
△	STRANG
●	ATTERIDG
X	JONES & PYLE
◎	HOLBROOK & BAKER
◎	SHERWOOD & JENNY

If the bubble cap to be used has 50 slots per cap and each slot is $\frac{1}{8}$ in. wide and 1 in. high, slot area per cap
$= 0.0433$ sq. ft.

It has been noted[5] that the best efficiency is obtained when the vapour velocity through the cap is such that the slot is just fully opened. CROSS and RYDER[3] give the following equation for the slot opening:

$$h = \left\{ \frac{2.60}{W} \left[\frac{R}{2g} \right]^{\frac{1}{2}} \right\}^{\frac{2}{3}} V^{\frac{2}{3}}$$

where h = slot opening, ft;
W = slot width, ft;
V = gas flow rate, cu. ft/sec. per slot; and
$R = \rho_V/(\rho_L - \rho_V)$.

Solving for V, we get $V = 0.0192$ cu. ft/sec. per slot
$= 0.0192 \times 50 = 0.96$ cu. ft/sec. per cap.

Thus the number of caps required

$$= \frac{41.2}{50 \,.\, 0.0192}$$
$$= 43$$

and total slot area
$= 1.86$ sq. ft.

If in the preliminary design we make the slot area one-tenth of the column cross-sectional area, then the latter is 18.6 sq. ft and the column diameter = 4 ft 10 in.

ENTRAINMENT

An entrainment of 10 mols liquid/100 mols vapour will drop the efficiency of the plate from 75% to 68%. For the purpose of this problem, this will be considered acceptable. The change in the composition of the vapour will be negligible.

The entrainment is then:

$$\frac{10 \text{ lb. mols liquid}}{100 \text{ lb. mols vapour}} = \frac{10 \times 34.8 \text{ lb. liquid}}{100 \times 36.5 \text{ lb. vapour}}$$
$$= \frac{348 \text{ lb. liquid}}{(365/0.08) \text{ cu. ft. vapour}}$$

The vapour flow through the column is 147,900 cu. ft/hr.

Therefore, entrainment $= \frac{348}{(365/0.08)} \times \frac{147{,}900}{1}$
$= 1113$ lb. of liquid per hour.

If the free area of the plate is assumed to be 85% of the column cross-section, then the plate free area
$= 15.8$ sq. ft.

The entrainment per sq. ft of plate area
$= 1113/15.8 = 71.2$ lb./sq. ft hr

PLATE SPACING

The vapour velocity based on the plate free area
$= 41.2/15.8 = 2.63$ ft/sec.

now if $\left(\frac{\rho v}{\triangle p}\right)^{0.5} = 0.04$

then $v \,.\, \left(\frac{\rho v}{\triangle p}\right)^{0.5} = 0.1054$,

also $\sigma = 20.8$ dyne/cm,

and $\mu = 0.58$ c.p.

Then from Fig. 6:

$\log 71.2 + 2.59 \log S + 0.4 \log 20.8 + \log 0.58 = 1.78$
or $S = 0.718$ ft $= 8.626$ in.

This means that the top of the slot is 1.125 in. above the plate. With the static submergence of 0.5 in. recommended by DAVIES,[3] this gives a weir height $= 1.125 + 0.5 = 1.625$ in., and a foam height $= 3.25$ in. The plate spacing therefore, $= 8.62 + 3.25 = 11.87$ in. A spacing of 12 in. would therefore be used.

The plate spacing thus calculated has to be checked for the liquid-handling capacity of the downcomer. The spacing calculated on the basis of entrainment should therefore be regarded as the minimum, which may have to be increased on account of the other factors that affect plate performance.

ACKNOWLEDGMENT

Thanks are due to Dr. S. M. Shah of the Department of Chemical Technology, Bombay University, for his helpful discussions on the subject.

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Sondes Place Research Institute

Open day to mark tenth anniversary

THERE are only two wholly British-sponsored research institutes carrying out research under contract. One of these, the Sondes Place Research Institute at Dorking, Surrey, recently held an Open Day to mark the tenth anniversary of its opening. This Institute grew out of a consulting chemical and chemical engineering practice established in 1936. It now has wide interests in chemistry, chemical engineering and mechanical engineering with a bias towards applied chemistry.

Exhibits at the Open Day were selected from current projects in order to demonstrate the wide variety of research and development work. In the ion-exchange membrane laboratory, work is continuing on developing new membranes and methods of making them on a large scale. This involves the operation of pilot electrodialysis units and preliminary assessments of new applications in the process.

Starting from an investigation intended to control "gushing" in bottled beer, there has arisen a fundamental research project on the stability of super-saturated solutions of carbon dioxide in aqueous media.

Sponsored by the Ministry of Power is work on developing fuel cells. These are restricted to gaseous fuels, but the cells are capable of working on a range of cheap industrial gases. A large battery with an output of between $2\frac{1}{2}$ and 5 kilowatts at 80 volts D.C. is under development.

The main pilot-plant house was equipped for investigating reactions in fluidised solid beds at elevated temperatures and for studying the removal of hydrogen sulphide from ammoniacal gasworks liquor by blowing air through it at 500 psi. Other plant exhibited included one for studies on polymer production to enable problems of monomer production, polymerisation, casting, curing, moulding and fabrication to be investigated.

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MECHANICAL PROBLEMS OF BUBBLE- AND GRID-TRAY DESIGN

by B. J. ROBIN, B.Sc., A.M.I.Chem.E.

A discussion concerning the advantages and disadvantages of various constructional methods for distillation columns

THE aspects of vapour-liquid contacting which receive most attention in the literature are concerned, naturally enough, with their performance. But apart from the operating characteristics of the various types of contacting tray, there is another side which is seldom mentioned. It might appear, at first sight, that the mechanical problems of accommodating vapour-liquid contacting trays inside an enclosing shell are simple, since there is no severe stressing problem as in pressure vessel design, and the loads would appear to be rather light, usually corresponding to a few inches of liquid. First appearances, however, can be deceptive and the purpose of this article is to present the many problems of mechanical design and how they can be handled.

The mechanical device performing the contact duty should ideally be infinitely light and stiff, handle the fluid streams passing through it without deformation, suffer no distortion due to thermal influences, have a long life, and generally be as economical as possible. The practical design will obviously be a compromise between these various requirements, and the final result will depend on the careful consideration of the many desirable features which the project engineer or the client may impose. It will be apparent that the importance which is attached to any particular feature will undoubtedly be influenced by the materials being handled and the process under consideration, but the prevalent traditions in a particular industry will inevitably be brought into consideration as well. Bearing this in mind, the following points have to be considered when preparing the practical mechanical design for a bubble tray:

(1) The mechanical load due to the weight of the material of which the tray is constructed.

(2) The dynamic loading due to varying liquid and vapour loads imposing flexure stresses on the tray.

(3) The accommodation of thermal expansion if the operating temperature is significantly different from atmospheric.

(4) The inclusion of access means for periodic inspection of the trays and internal tower wall.

(5) The load imposed by maintenance men on the trays if internal access is required.

(6) The means of cleaning individual trays mechanically, if required.

(7) The provision of access to enable individual tray designs to be altered in a minor fashion due to change in design conditions.

The emphasis which will be placed upon these various points will be affected by the design duty of the tower concerned, as defined by the process and project engineers initiating the job. For instance, it is quite possible that for more arduous conditions an annual internal column inspection may be thought necessary or even enforced by insurance company regulations. Also, in the case of pressure or vacuum column design, it is frequently advantageous to fabricate the column in one piece and thus avoid the use of flanged joints. It is now possible to consider how the various methods of tray construction fulfil the above requirements.

The One-piece Tray

The traditional answer to this construction problem was the cast-iron one-piece bubble-cap tray. In this case, the tray is usually cast in one section, including risers and downcomers, the bubble caps being cast separately and then fastened, sometimes by hook bolts, to the individual risers. Separate downcomers bolted to a machined pad are also used. The tray section is machined around the edge in order to obtain a good joint with the flanged column sections between which the trays are clamped. These column sections are usually the same length as the tray spacing used, and it follows that there are as many flanged joints as there are trays. In a development of this idea, the trays are assembled in sections, in sets of two or three. The lowest tray has the smallest diameter and is thus able to pass the upper tray supporting rings which are cast into the column wall. In recent years sectional cast-iron trays have been developed, but the main limitations of this material still apply.

Cast-iron trays, although they are undoubtedly heavy, do have the advantage of a robust construction with generous wall thicknesses, and are used when the design requirements of the tray are not too ambitious, when

Mr. Robin *is Head of the Chemical Engineering Department of Metal Propellers Ltd., Croydon*

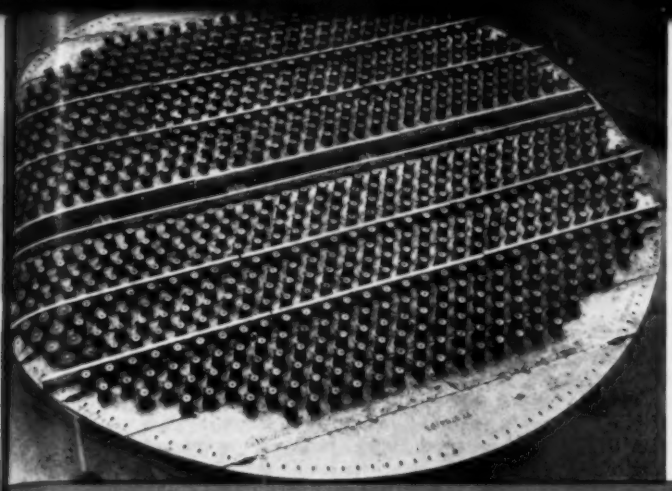

Fig. 1. A 16-ft diameter twin-type tray, two-pass, three-level, constructed of 12-14 Cr. steel. The total number of 4-in. caps per tray is 794.

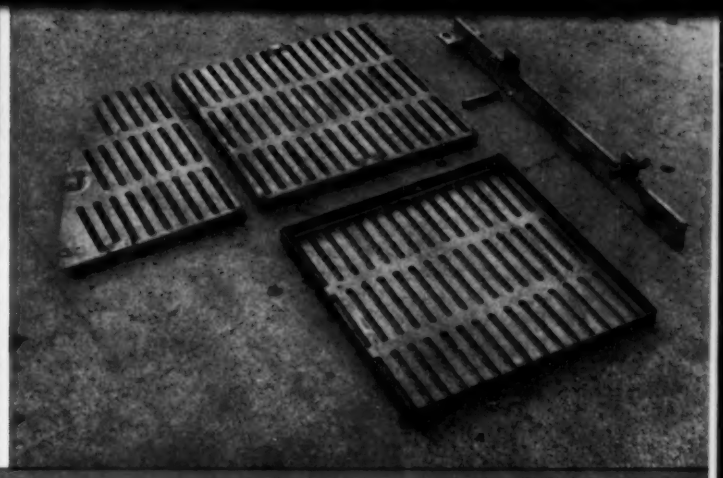

Fig. 2. Sections of a grid-tray. These sections are installed in 16 ft. diameter distillation columns at "Shell" Refineries at Stanlow and Shell Haven.

weight is no problem and usually when access is not expected at intervals of less than about ten years. The detail design of the tray is naturally limited by known casting techniques, and abrupt changes in section or excessively long upstanding parts have to be avoided as far as possible. The minimum thickness requirements for successful casting means that the wall thickness of the various members is rather great, and a substantial portion of the tray area is lost for fluid handling. For the same reason, large cross-sectional area downcomers are difficult to construct and there is a tendency for downcomers to be undersized. The resulting tower with trays is very heavy, and the foundation and erection costs are likely to be appreciable. All-up weights of 100 tons are quite normal, and individual sections may weigh up to two tons. Heavy lifting gear must be available on site whenever maintenance is to be carried out, and the civil engineering design must allow for this and for the heavy ground loadings involved. Thus, as is usual in cast forms, the designer is limited by the material being used, and the practical techniques.

One-piece trays are also constructed from wrought materials. In the past such trays were constructed from copper, but this material is not applicable in all corrosive environments. This method of construction has, in more recent years, been applied to other wrought materials, including the corrosion-resistant alloy steels. Such trays may be supported in a similar manner to the cast-iron tray, i.e., clamped to the flange, but more frequently they are made to offer a clearance fit inside the wall of the column; the annular space is then filled with some type of plastic packing, usually asbestos base. Alternatively, the trays may be welded in place. Such trays are of two general types:

(a) a direct descendant of the cast-iron tray of stiff, robust construction, being self-supporting across the column diameter; and

(b) a lighter weight construction using vertical supporting rods evenly spaced in the tower across the sectional area.

The first type may be admissible, though it will have the disadvantage of resulting in a very heavy tray, on a large-diameter tower. Designs are also put forward of the second type, which allows some mechanical flexibility in the tray floor. Such flexibility is, of course, required to absorb thermal stresses, but, at the same time, the design problem is complicated by the need to maintain accurate flatness limits on large spans. A limit flatness tolerance of up to $\frac{1}{8}$ in. is frequently specified on diameters of 10 ft, and this flexibility in the tray floor enables limited on-site adjustments to be made.

Naturally, at the design stage, a particular figure for static or dynamic seal is borne in mind, and any departure from the flatness limits will mean that the seal is either exceeded at some places or is too little at others. In the case of a bubble-cap tray this can easily lead to vapour bypassing or liquid dumping, while, in the case of a free area tray, uneven distribution of liquid flow will result. In either case it is apparent that adequate limits must be placed on the out-of-level and flatness tolerances which may be permitted in the finished design. Since, in this type of tray, all thermal expansion must necessarily be transmitted to the outer edge, the design of the packed joint can be quite difficult, even for moderate temperature conditions. It may be necessary to provide sufficient flexibility to accommodate perhaps $\frac{1}{4}$ in. of radial movement all round the tray.

An alternative method of construction which has been used in Germany is to use a light-gauge tray floor with an "egg-box" stiffening lattice on the underside of the tray. Such a construction, being reasonably stiff, can be supported from the outside edge only, but it would seem that the mechanical strength is dependent upon the large number of tack welds which hold the structural elements together. One-piece trays have also been installed by welding the outer edge directly to the wall of the column. Such construction is usually restricted to cases where the liquid flow is very low, and, of course, access to the trays is virtually impossible once they have been fastened in place, though access may not be necessary for clean duties. This method allows no margin for thermal expansion, and tray flatness is taken on trust. For small columns where this type of tray is usually used, it is necessary to build up the column in lengths equal to one tray spacing.

The Sectional Tray

A totally different approach to the mechanical design problem is involved in the design of a sectional tray. In this approach the basic units are comparatively simple items from which a complete tray can be built up inside the tower. This type of construction is used in the Glitsch "Truss Type" patented method of construction, which has been in service for many years all over the world. The design is based on a detailed mechanical engineering assessment of the problems involved, and the solution is applicable to any type of contact tray (Fig. 2) as well as the bubble-cap tray for which it was originally developed

(Fig. 1). Since the tray is sectional, it can readily be dismantled at any time, and it is therefore usual to arrange for all the sections to be of such a size that they pass through a given size of opening in the wall of the vessel. This opening is usually a manway of 18 in. to 24 in. in diameter.

Since the intention is to handle these various sections manually through a manway, they must not be too heavy; consequently, it often becomes necessary to use separate load-bearing members and tray floor sections. Thus a skeleton of lightweight beams or "trusses" can be built up and the floor plates are then laid individually on top of this skeleton. Such a design enables extreme flexibility in tray layout to be obtained, since the skeleton is independent of the tray itself and can be arranged to leave large openings where necessary.

As the diameter of the tray increases, the stress design problems become more complex. The skeleton may then be split up into a comparatively small number of substantial main beams which are of sufficient strength to span the whole tower diameter without significant deflection, with the intermediate area filled in by trusses of the same type as are used on smaller diameter trays. The open area between the members of the skeleton is kept to more or less the same size, whatever the tray diameter, so that it is possible to standardise on the tray floor sections.

The sectional design is essentially a method of producing a stiff, flat tray from the minimum weight of material, by disposing this material in the right place to do each job. In the case of expensive alloy materials, it is essential to keep the overall weight as low as possible and the sectional tray offers an ideal solution. The floor plates are laid on top of the supporting skeleton and the peripheral tray ring, and it is usual to insert asbestos jointing material between each floor section and the supporting member. A substantial clearance is allowed between adjacent sections and clamping devices are used rather than through-bolting. Thus, there is considerable latitude in assembly tolerances both in manufacture and installation, and it is possible to carry in stock spare sections of the tray with the confidence that they can be used without modification on site. In larger towers the ovality tolerance on the diameter may be appreciable in spite of the best efforts of the tower maker and care in transport and erection. The tolerance on the outer floor sections which are supported by the tray-ring welded to the tower wall permits such ovality to be accommodated.

Factors Affecting Tray Construction

A detailed examination of the various factors affecting tray construction can now be made:

Tray Flatness

Whichever type of tray is adopted, it is essential that the tray floor remains flat under all envisaged design conditions. Possible deflection from liquid loading, thermal expansion or vapour thrust must be catered for. In the cast-iron tray, the massive construction provides sufficient material to ensure that the original shape is maintained, provided that the castings have been matured before machining. In the one-piece tray, the flatness in service is dependent upon tray flexibility and support methods, combined with a "hunch" about the behaviour of an indeterminate structure under mechanical and thermal loads. While the test shop assembly may give satisfactory results, the service behaviour must be taken on trust.

In the sectional tray, the supporting framework can be manufactured separately from the tray floor, and it is therefore possible to arrange for the beams to be as straight as is necessary. The strength can be built up by the designer in order that the required flatness is maintained under operating conditions. Since the tray floors need only be of quite thin material, it can then be confidently expected that they will align themselves with these level straight beams, and the resulting tray floor will therefore be flat. The behaviour of all these simple members in service can be confidently predicted, since they act independently of each other, and the resultant structure is statistically determinate.

Thermal Expansion

As discussed under tray flatness, the cast-iron tray, by reason of its heavy form, is able to withstand the compressive forces set up by thermal expansion of the tray, within reasonable temperature limits. It is of interest to note that, by reason of the large mass of metal used in constructing this type of tray, the heat capacity is appreciable, and this may well affect the time taken to bring the column on and off stream, which is especially important in a batch process.

In the one-piece wrought tray the periphery is trapped by the wall of the column, and all thermal strains must be transmitted to this outer edge. Since the tray is usually designed to have some flexibility, there is a limited ability to absorb thermal stresses. Apart, therefore, from the very small deformation possible in the plastic packing seal between the edge of the tray and the column, any expansion will be taken up by distorting the tray floor.

One of the prime advantages of the sectional tray is its ability to cope with thermal expansion problems. The individual sections of the tray floor are normally held to the supporting skeleton by frictional clamping devices. The sections can therefore move slightly under the influence of thermal stresses, and any tendency to distortion is eliminated. The members of the skeleton, since they are designed only as load-bearing elements, can be allowed sufficient room for expansion.

Tray Support

Normally with sectional trays both the skeleton and outer floor plates are supported upon continuous rings welded to the internal surface of the column wall. Great care is taken to ensure that these rings are installed at right angles to the column centre line and in combination with the provision of true, flat, supporting beams a level tray is ensured. In the case of larger towers, over 10 ft in diameter, the total weight to be supported becomes too heavy for a simple ring; separate footstep bearings for the heavy main beams are then used.

In the case of one-piece trays of the semi-flexible type, as outlined above, the supporting rods are usually provided with adjustable nuts which can be set on site as each tray is lowered into position. Provided the tray is reasonably flexible, a good approach to a flat surface can then be obtained, although this may well be upset in service by movement resulting from temperature stresses. It is important to realise that in this case the whole weight of the set of trays in the tower is transmitted to the base, where substantial brackets carry the support rods, and the heavier construction bottom tray.

Column Access

It may well be necessary to make provision for regular internal inspection, as required by insurance company regulations, and for maintenance purposes. With cast-iron construction, access is obtained by completely stripping the column and trays, the whole column structure being taken down, inspected and then later re-assembled. The time required is substantial, heavy lifts are required, and a great many joints must be broken and re-made. In the case of a vacuum column, the procedure is especially objectionable.

Columns with one-piece fabricated trays may have a removable cover. A suitable lifting device is then arranged to lift out each tray one by one. The packed joint around the tray periphery is broken and any intermediate supports are removed together with the tray. The usual concern in this instance is possible ovality of the column consequent upon settling and low-temperature stress relief. This can make the removal of these trays rather a difficult operation. This design is, therefore, only adopted when the interval between inspections is likely to be long.

In the case of the sectional tray the spacing alone limits accessibility. In the chemical industry during recent years, the tray spacings generally used have decreased to 6-12 in. For excise reasons, or the requirement of rather frequent maintenance on corrosive or fouling processes, chemical plants are normally erected inside buildings; for this reason, economy in headroom is of the utmost importance.

In the petroleum industry, however, ground space has to be fully utilised so that column heights are not restricted. On the other hand, access to the tower internals and minimum downtime is of prime importance, annual inspections being the rule rather than the exception. Thus, in this industry, tray spacings of 18-36 in. are used. Two entirely different sets of conditions therefore exist.

Importance of Tray Spacing

Sectional trays can easily be designed with a removable plate say 24 in. × 18 in. in the centre of the tray. This is commonly known as a manway section (Figs. 3 and 6). If entry is to be made from the bottom, removal of the bottom-tray manway is quite simple. The operator can then pass to the second tray, and here, if there is a low-tray spacing, there may not be sufficient clear height between the trays to enable the manway section to be removed to one side of the central shaft. After several more manways have been removed, a second difficulty appears. In order to work up the tower, it is necessary to be able to flex the average human leg in the available space between the trays. This spacing will thus be determined by the average length between the kneecap and the heel, and this is generally about 18 in.—the figure for minimum tray spacing. A large tray spacing, however, does allow a significant increase in throughput for a given bubble tray, owing to the decreased liquid entrainment at a given vapour velocity. There is something to be gained, therefore, in using a tray spacing of 18 in. or more, since the tray throughput is increased (or the column diameter reduced for a given throughput) and easy access to the tower interior is provided. Also, with large-diameter towers, the depth of the load-bearing members becomes greater in order to withstand the loads involved without intolerable deflection. Sufficient clearance must be left between the lower side of these members and the highest portion of the tray below in order to allow a reasonable degree of vapour cross-flow, and also to permit human access to the remote parts of the tray. Thus in the larger diameters a generous tray spacing is desirable. In designing a sectional tray, the mechanical load which will be imposed by maintenance men on the tray support members has to be borne in mind. It is usually assumed that for trays below about 8 ft diameter one man only will be present inside the tower, due to physical space limitations, while above this limit at least two men will be employed.

These points must be carefully assessed together with the civil engineering requirements at the initial design stage. It can be seen that the decision made on this one feature of the tray spacing alone can have far-reaching results, and it is essential to consider it as early as possible in the project design.

In the example cited above, entry to the column would be through a bottom manway and the column can then be climbed through the tray manways using the trays as the steps of a ladder. It is also possible to consider top access, when it is usual to provide an outside cat ladder to a platform at the top of the tower. In either case, the trays may be removed in sections, if necessary, and lowered, usually by a davit and ginny wheel, to the ground. The interior of the column can then be inspected. The case of small-diameter towers is considered separately.

Tray Leakage

A cast-iron one-piece tray normally offers no problem for liquid leakage between trays. The downcomers are commonly bolted to the tray surface, but it is possible to use sufficient metal to ensure a robust joint. Since tray sections are clamped between column sections, any leakage will be evident from outside the column and will thus not pass undetected. In the case of the wrought one-piece tray, it is common to include around the periphery of the tray an upstanding rim somewhat higher than the maximum working liquid level which will be expected on the tray. A packing ring is then used outside this outstanding ring. While such a tray can be made bottle tight under static conditions, particularly by paying attention to the joints at the tray support rods, under operating conditions a layer of foam will build up considerably higher than the maximum working liquid level. Thus the packing is continually wet and, unless arrangements are made to keep it tight at all times, liquid leakage can occur around the tray periphery. This problem is complicated by thermal expansion and an attempt is made to meet it by using a packing which has a reasonable degree of plasticity. Any distortion which arises during installation of a one-piece tray does, of course, render the sealing problem far more difficult to solve.

The sectional tray does, of course, possess a leakage potential, since many joints have to be made between the tray floor and the supporting beams. But under dynamic operating conditions a substantial vapour differential pressure exists across the tray which tends to oppose tray leakage, whatever the design employed. In some cases it has been the practice on known critical applications to design bubble-cap trays with deliberately high pressure drop in order to enable jointing to be eliminated completely. By attention to use of the joint material and the method of assembly, the liquid leakage rate through a sectional tray can be reduced to any desired degree. In relation to normal liquid flows in the tower, a well-assembled tray can be made bottle tight. In the normal method of construction, asbestos listing tape is used between the tray floor and the various supporting members, and frictional clamps of various types ensure a continuous contact pressure on this jointing. Since the trays are sectional, the movement of each part under thermal stress is quite small and the joints, once made, are reliable. If, therefore, the leakage problem is adequately assessed in relation to the liquid downflow in the process design stage, suitable arrangements can be made in the mechanical design to meet any desired conditions.

Complicated Designs

It is frequently neccessary when considering column internals to accommodate rather complicated designs, such as accumulator pans, for the separation of two liquid phases inside the tower. If these are constructed in one piece the total weight becomes rather great and they are awkward to install. The structural problems are severe, since the weight of structural material per unit area is much higher than that on a simple plate design. In such a case it is either desirable to break the column by a flanged joint at the point where such a device is included,

or to use the sectional tray principle, thus enabling the load to be carried by means of a separate strong skeleton. Since the skeleton is entirely separate from the device concerned, it can be designed only with structural considerations in mind. A complicated device can then be built upon this skeleton in any desired manner. As with the straightforward bubble tray, such devices can be built up from small sections which may be passed through a manway in the column wall and assembled inside the tower (Fig. 4). As the ingenuity of process designers becomes greater, so these devices become more involved, but using the sectional tray principle, the problems can be overcome by building up from comparatively simple subsections.

Vapour Surge Hazards

In the course of distillation operations, especially those occurring at high temperatures, it is quite possible for minor explosions to take place inside the tower, frequently without any evidence that such a disturbance has occurred. The admission of water to a high-temperature vessel or the inadvertent inclusion of small proportions of air in an inflammable mixture may lead to such incidents, which emphasise the advantages of a resilient tray design. A one-piece or stiff tray will resist the force of the sudden pressure rise and will tend to be severely damaged, while in the case of the flexible sectional tray, small surges will be absorbed and large surges will only deform the sections which can be subsequently straightened for re-use. This work can be done on site with simple tools.

Transport Problems

The problem of transporting these contact trays is naturally related to their size and weight. If one-piece trays are of such a diameter that they can be transported flat, it is possible to arrange suitable supports so that distortion is avoided. If, however, the diameter exceeds that which can be handled flat by road transport, say more than 10 ft, then it will be necessary to transport the tray on edge. In this case it is necessary to supply jigs to support the trays firmly and avoid any risk of distortion. Even so, owing to the heavy weights involved, on-loading and off-loading present quite difficult problems. As explained above, it is usually desirable to build some flexibility into a large tray, and the risk of distortion in transport is, therefore, rather high. Again, it is necessary to consider the heavy lifting tackle which must be provided on site for assembly of the tray into the column, and for any subsequent maintenance work which may prove necessary. Lifting jigs must again be provided to avoid distortion of the tray at all times. It is possible for large trays to be installed in the column at the maker's works on a "once and for all time" basis, but it is then unlikely that any full inspection could be carried out, and tray distortion would, therefore, pass unnoticed. It is generally preferable for the trays to be installed on site so that final checks on tray dimensions may be made.

In the case of sectional trays, it is usual to crate the various items and send them to site separately from the column. It has been found perfectly feasible for these trays to be installed by personnel unfamiliar with this construction. It is usual for one member of the team to be responsible to the project engineer in order to ensure that the final tray meets the original design specification. The whole tray is built up by repetition of standard sub-assembly techniques, and it is found in practice that the work proceeds smoothly when carried out in this manner. Since the separate parts are transported in crates, there is very little risk of distortion, and provided the tower attachments are correctly sited, it then follows that the resulting tray will be level and flat. These general principles apply whatever the size of tray and have been proved in practice for trays of up to 25 ft diameter and over.

Special Problems in Smaller Diameter Columns

On small projects it is frequently necessary to design columns having a diameter of less than 3 ft. While packed columns may be considered acceptable by the project engineer for the very small sizes, plate trays may be preferred, particularly in the intermediate and larger range. These small plate-type bubble trays present their own particular design problems due to their physical size limitations. Access to the column interior is not normally possible, and a design must be evolved to avoid detail assembly work inside the column. A small tray is inherently stiff, so the mechanical design from this point of view presents no problem. Due to the small access space available inside the column, however, it is not possible to use sectional trays, and a one-piece tray is always used. If a flanged column is acceptable, as described above for use with cast-iron trays, then each tray may be clamped between the flanges. This is not, however, an elegant solution, owing to the numerous leakage points which arise. It is also very difficult to design free-standing columns and expensive to design pressure columns in this manner. Thus the need arises for a peripheral sealing device such as has been described for the larger one-piece wrought trays. Since

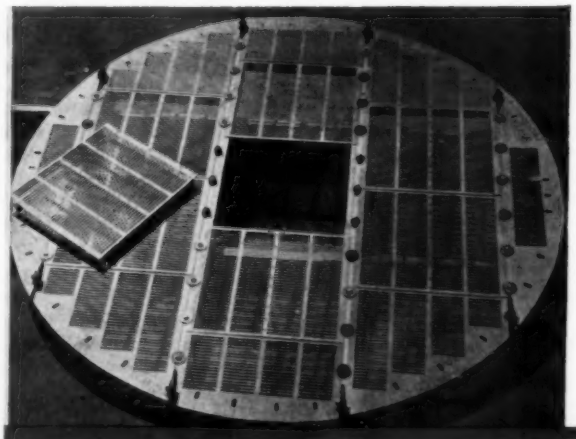

Fig. 3. A typical sectional grid-tray assembly with centre section removed.

Fig. 4. A draw-off pan 8 ft 10 in. in diameter for a 9-ft i.d. tower (Constructed from 12/14 Cr. alloy.)

internal manual access is not possible for tightening packing clamp rings, any device used must be self-sealing; it is usual to use trays of "cartridge" type which carry their own packing device and which can be inserted into the column from one end (Fig. 5). If it is necessary to inspect the trays, then they are removed one by one; in view of the small size and comparatively light weight, this does not usually present any great problem.

Material of Construction

In the early days of contact tray design, the only materials available for tray construction were cast iron and copper. Nowadays alloy steels have entered the picture; they are more expensive than cast-iron and it became essential to reduce the construction weight to a minimum by taking advantage of their much higher tensile strength. The first step in this direction was to fabricate trays from wrought material in the one-piece construction outlined above. The sectional tray carried this economy of material a step further, and the thickness of material used is such that, even with a comparatively ambitious mechanical design, the thickness of material is as much limited by the proposed corrosion allowance as it is by mechanical considerations. At the same time, due to steadily rising labour costs, it became more important to view critically the cost of maintenance and inspection. It therefore became advantageous to consider a lighter weight construction than with cast-iron, and trays constructed from wrought mild steel were further considered. Although the corrosion resistance of mild steel is not as good as that of cast-iron, nevertheless it is suitable for quite a wide range of process duties. It is, of course, necessary to include a substantial corrosion allowance to allow at least for atmospheric corrosion on shut-down, even if the process liquor has no corrosive effect on mild steel. Thus tray floors $\frac{1}{4}$ in. or even $\frac{3}{8}$ in. thick are quite usual in mild-steel construction and standard rolled steel sections may be used for tray support members.

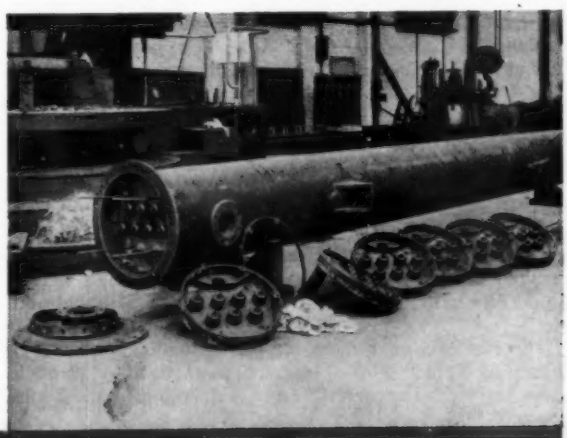

Fig. 5. A small-diameter bubble-cap column showing method of assembly and sealing.

Fig. 6. A 6 ft 4 in. diameter tray with rectangular cap assemblies using Glitsch patented "snap-in" frogs.

Fastening Devices

The fastening devices used in tray construction present peculiar problems apart from the usual mechanical considerations; the influence of temperature changes and the frequently highly corrosive environments have to be considered. In the cast-iron tray the weight of the bubble caps is substantial. It is possible to rely upon this weight to hold the cap in position on top of the riser, but more usual to employ hook bolts and nuts as a positive fastening device. The downcomers may be bolted through the tray floor on to machined pads, but the mechanical load involved is negligible and, therefore, the fastening problem is not difficult. The tray is clamped between the column sections by external bolting, to which access can be obtained should the need arise.

Threaded rods are used to support the central zone of a one-piece semi-flexible tray and these are usually arranged with protective collars which enclose, so far as possible, the threaded portion of the support rods. The weight of the trays bearing down on these support rods tends to prevent a movement of the threaded parts. At the periphery of the tray it is usual to use a packing compression ring which is forced downwards by jack screws at fairly frequent intervals. The continual upward pressure of the plastic packing exerts a restraining force on these screws which usually helps to keep them in position.

For sectional trays, it is usual to employ friction clamps for fastening the tray floor sections to the supporting skeleton. These devices have the added advantage that while the friction clamp offers continuous pressure on the tray floor section, it also offers upward pressure on the bolt head, thus acting as a locking device. The bubble caps, if used, are fixed to the risers by a suitable setscrew assembly and the risers are held into the tray floor either by the same setscrews or are expanded and welded in position. In this case the flexure of the cap enables a constant pressure to be exerted upon the fixing screw which is locked in position. The structural members of the supporting skeleton are fixed to each other by bolts and nuts as in normal structural engineering, while attachments to the tower wall are made using frictional clamping devices to enable a reasonable degree of relative movement to be accommodated. It is, of course, necessary for all fastening devices to be made of a material which is compatible with the material of construction of the tray. In cases where it is advisable to avoid the use of threaded parts due to severe fouling, wedge fastening devices using slow taper wedges may also be employed. While it must be appreciated that it is more difficult to avoid tray leakage when using this fastening device for low pressure drop, the problem can be overcome by attention to detail, and, in any case, the performance on fouling duties will be satisfactory. The same general principles of use apply as with threaded parts.

Acknowledgments

The author wishes to thank Metal Propellers Ltd. for permission to use Figs. 1, 2, 4, 5 and 6, and F. W. Glitsch & Sons, Dallas, for permission to use Fig. 3.

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RECTIFICATION THEORY AND PRACTICE REVIEW

This article reviews researches in the field of rectification carried out in the U.S.S.R. during the past decade

by M. E. AEROV, D.Sc., M.Sc., and V. A. MALIUSOV, M.Sc.

THERMODYNAMIC studies of the equilibria of multi-component systems have been extensively carried out. A special monograph[b12] and a number of papers have been published on this question; the conditions of application of KONOVALOV's Laws to such systems have been ascertained; the effect of pressure on the composition of binary azeotropes has been studied;[b6] an investigation has been made of the azeotropes of three-component mixtures of liquids of limited mutual solubility;[b7] methods have been suggested for calculating the liquid-vapour equilibrium of binary systems through the vapour pressures of some components and two experimentally found intermediate points;[b8] methods for calculating the evaporation heats of three-component mixtures have been suggested;[b9] apparatuses for studying the liquid-vapour equilibrium of stratified systems have been developed,[b10] as well as a unit which makes it possible to observe phase equilibria and volumetric relations in liquid-gas systems under pressure.[b11]

Considerable attention has been paid to the theory of selection of solvents for separation by extractive rectification. Relationships have been suggested for determining the volatility factors of three-component mixtures through the properties of the binary systems.[b14] The use of data on the mutual solubility of mixtures[b15] and on the boiling points of azeotropic mixtures[b16] has been proposed by binary systems for the selection of separating agents. In addition, experimental studies of the liquid-vapour equilibria of about 40 binary and ternary mixtures have been carried out.

Film Rectification

A large number of publications have contributed to the working out of the theory and practice of film rectification. An investigation has been made of rectification in tubes with sprayed walls under conditions of laminar and turbulent vapour flow.[c1, c2]

The authors showed that the expression for the height of a unit of mass transfer ($h_{or} = 0.068\ d.\mathrm{Re.Pr}$) suggested by them for laminar vapour flow agrees better with experimental data than the equation given elsewhere,[c3] which cannot be used for systems deviating considerably from RAOULT's Law. The correlation they suggest holds up to velocities corresponding to Re_{cr}—the point of transition of laminar into pseudoturbulent flow; it appears, however, that the value Re_{cr} itself depends on the tube diameter. This has a considerable bearing on mass exchange in a turbulent flow. The authors point out that earlier published data on film rectification are in good agreement with the equation suggested by them for turbulent flow.

The authors have shown that the data on film rectification[b4, b5] published before are in accord with the equation suggested by them for the turbulent flow. Research into the hydrodynamics of flow through sprayed-wall tubes has resulted in equations for calculating the thickness of the liquid film with counter and co-current flow of liquid and gas.[c6, c7]

Theories have been proposed for the undulations in thin layers of liquid[c9, c12] and for the mass transfer through them when the controlling factor is diffusion in the liquid phase.[c11, c12]

A number of papers have concerned themselves with the study of mass transfer and the development of designs of stationary columns for film rectification and absorption; various designs of tubular columns are investigated in references [c13, c14, c15, c16, c26].

Film columns with plane-parallel packings are probably of even greater interest than tubular columns, since the cross-sectional area for the passing of vapour in such columns is very close to the cross-sectional area of the apparatus. A design of plane-parallel packing consisting of sheet iron faggots was proposed. Such a packing with 10-mm spacing between the sheets is no less effective than a 25-mm diameter ring packing, and is much superior to it in hydrodynamic properties. Plane-parallel packings of glass cloth, iron and steel plates were also investigated.[c19-c21]

Designs of horizontal columns with slowly rotating plane-parallel packings have been proposed and considerable work has been done on the investigation of film columns with rapidly rotating horizontal and vertical rotors. The performance of PODBIELNIAK-type horizontal contactors has been studied and a method of calculating them has been suggested.[c24, c25, c26, c27]

The experiments show that horizontal contactors are effective only at low vapour speeds (0.1 to 1 m per sec.). At high vapour speeds (15 to 30 m per sec.) the efficiency of

Dr. Aerov *graduated from the Moscow Chemical Machinery Institute in* 1935 *and obtained his M.Sc. in* 1938. *After distinguished war service, he resumed his researches in heat-and-mass-transfer processes, and in* 1951 *took the degree of D.Sc. At present he is Head of the Research Institute of Synthetic Spirits and Organic Products.*

Mr. Maliusov *took his M.Sc. in chemical engineering in* 1952 *and is at present engaged upon research at the Karpow Physico-Chemical Institute in Moscow. Low-temperature mass-transfer processes and molecular distillation are his particular interests.*

these devices is usually small, equalling about 10 perfect plates with a spiral length of 22 to 30 mm.

Investigations[c28, c29, c30] of the performance of UREY-PEGRAM-HUFFMAN-type[c31] vertical rotor columns have also been made. On rectifying water in a 150-mm diameter column with 200 pairs of cones, a hydrogen isotope separation[c29] corresponding to 100 perfect plates was obtained. A column of similar construction was investigated while rectifying alcohol-aqueous mixtures.[c30] The authors came to the conclusion that the efficiency of this apparatus is high, but its capacity is low, making it eligible only for low-tonnage production.

A number of publications have been issued on vertical tubular columns with revolving rotors turbulising gas and liquid. Some laboratory-type rotor columns and one large-size four-cylinder metal column 250 mm in diameter and 500 mm high were investigated[c32, c34] when rectifying a benzene-dichloroethane mixture.

The equivalent height of theoretical plate (HETP) for three laboratory columns under a load of 300 cc per hr and with a rotor revolving speed of 1400 rpm was from 1.8 to 3 cm. Approximately the same results were obtained in a study of the performance of laboratory columns with rotating tapes.

Investigations of the rectification of a number of organic mixtures in columns with revolving blades of various geometrical patterns resulted[c35] in an equation for estimating such columns when used in contacting gas and liquid phases.

Rectification in Packed Columns

The hydraulics of columns with commercial-size Raschig ring packing and mass transfer in gas pelliche (film) were studied systematically between 1936 and 1944, and the results were set forth in a monograph.[d1] Afterwards, on the basis of these works and the data of other investigators, relationships were suggested for determining the hydraulic resistance of non-sprayed[d2] and of sprayed[d3] packings, flooding, hold-up and pressure losses.[d4, d5]

In subsequent investigations studies were made of the spreading of liquid over a real surface from a point source and of a specific type of flow—capillary-hydrodynamic,[d8] which occurs through the action of capillary forces and affects the extent to which the layer of the liquid spreads over the porous surface of the packing; the uniform distribution of the liquid in such conditions affects rectification favourably.

The efficiency of packings for rectification was studied mainly in laboratory-size columns.[d17, d18] Exact data were obtained[d9] on liquid-vapour equilibrium for a carbon tetrachloride-benzene mixture. For determining the efficiency of column packings a benzene-thiophene mixture was used in conjunction with radioactive indicators.

A great deal of work has been carried out on rectification processes taking place on small-size (8 to 15 mm) non-regular packing.[d13] A study has been made of rectification in packed columns under conditions of continuous liquid and disperse gaseous phases.[d14] In such conditions, which the authors have termed "emulsifying conditions", the amount of mass transfer per unit volume reaches the maximum. Units have been designed to operate at high efficiencies under such conditions,[d19] and equations have been suggested for determining the HETP and the pressure loss.[d15] The efficiency and pressure drop over regulated multi-layer sieve packing for the air-water system[d16] have also been studied.

Rectification in Bubble-plate Columns

Determination of the Driving Forces of the Process and the Number of Transfer Units for Bubble-plate Columns

To calculate a bubble plate as a mass-exchange apparatus, an expression must be found for the motive forces of transfer on a plate under conditions of cross flow, complete and partial mixing of the liquid and gaseous phases. This question has been the subject of several papers.[e1, e2, e3, e4, e5] Graphical methods have been suggested[e1] for constructing the required number of actual plates on an y-x diagram, and a generalised equation has been deduced[e3] for calculating the driving forces for various cases of feeding the spray to the bubble plates. One publication[e5] discusses the question of the rules applying to increased numbers of perfect plates and increased numbers of transfer units to bubble column equipment.

Sieve Bubble Plates

An equation has been suggested for calculating the hydraulic resistance of sieve plates, this equation having been confirmed experimentally in columns from 80 to 3200 mm in diameter with various working media.[e6, e15]

From this equation the conditions of hydraulically stable operation of sieve columns have been determined.[e7] For sieve plates the dependence of the height and gas saturation of the bubbling layer on the design, vapour and liquid loads and the physicochemical properties of the working media has been investigated.[e11, e15]

Studies of the causes of non-uniform gas distribution over the plate surface and of seepage of the liquid through the sieve apertures have been made,[e8, e10, e15] as well as of priming and its dispersity for various small sieve-plate spacings. It has been shown that in the absence of "froth" priming the plate spacing is limited by the throughput of the overflow device.[e9]

Equations applicable to various types of plate for calculating the throughput and choking limit of several main types of overflow device have been suggested.[e6, e15]

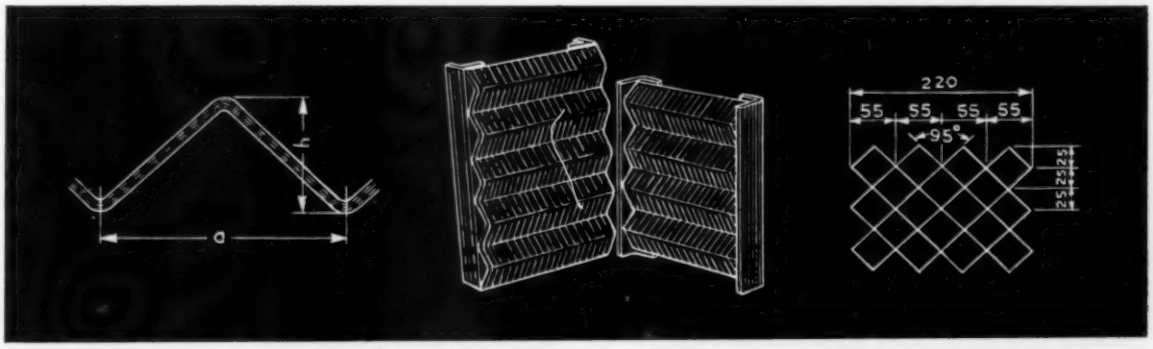

Fig. 1. A supported mesh packing with method of assembly.[e19] Dimensions are in mm.

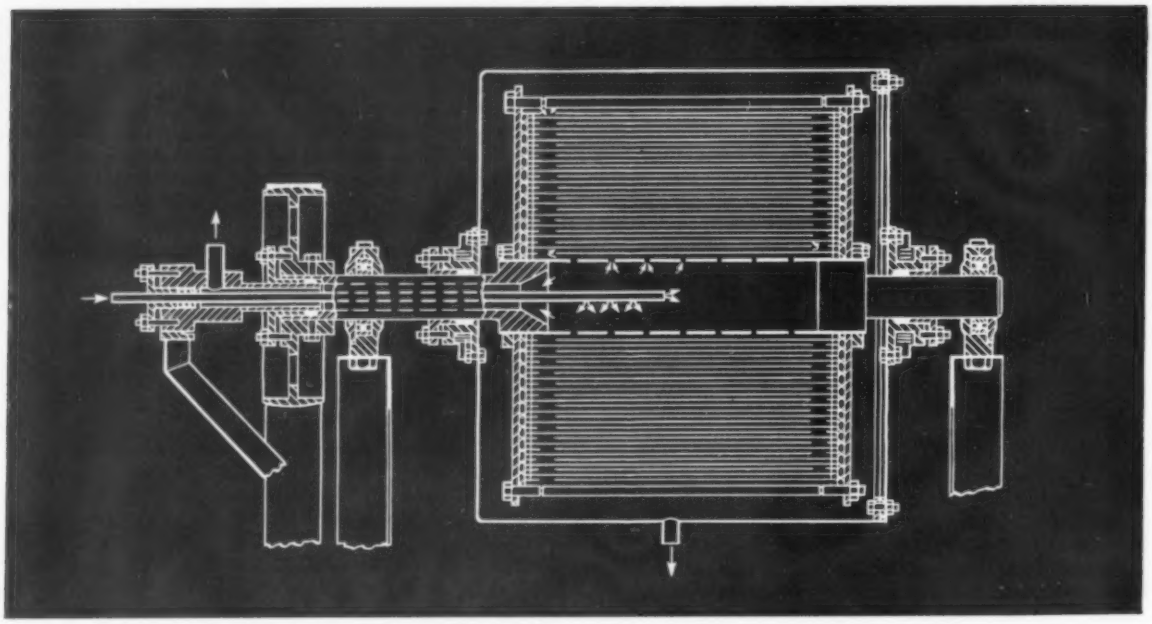

Fig. 2. Horizontal centrifugal rectification machine. Procedures for designing such machines have been published by Gelperin and others. (Reference [e25].)

The mass transfer in the liquid and gaseous phases on sieve plates has been studied,[e16] and an approximate method has been evolved for designing sieve columns and scaling-up from small-scale experiments.[e15] A possibility of increasing the efficiency of oxygen plant sieve columns is shown without perceptibly inhibiting their separating action, and a corresponding type of plate has been suggested. The principal points of the above studies have been verified in industry in towers up to 3200 mm in diameter.

Studies have been made of the hydraulics and mass exchange on sloping sieve plates,[e19] as well as of the hydraulics of bubble plates.[e20, e21]

Non-overflow Bubble Plates

The hydraulics of mass transfer on non-overflow bubble plates (analogous to "Turbogrid" and "Dual flow" plates) were also investigated by Soviet research workers.[e22, e23, e24, e25, e26]

The hydraulic resistance of grating-type and perforated plates was measured in a special section in rectification towers with 3 to 6-mm apertures for an air-water system, air-water glycerine solutions and for liquid air and liquid hydrocarbon distillation, and an equation for determining the pressure loss was proposed.[e22] The efficiency of grating plates was determined over a wide range of velocities in a column with 45 plates 100 mm in diameter,[d23] and it was found that a threefold change in output did not lower the efficiency of the plate below 0.6, while a maximum of 0.85 was obtained. Experience in the successful operation of towers with grating-type plates up to 2.0 metres in diameter and at pressures of up to 25 atm. gauge with liquids containing solid phases in suspension has also been obtained.[e26]

Vacuum Rectification and Molecular Distillation

An important present-day problem is that of creating equipment for separating thermally unstable mixtures. In many cases it is desirable to have columns with the efficiency of 5 to 15 perfect plates with a pressure of not more than 1 to 3 mm Hg in the column still.

For this purpose a study was made of various designs of laboratory-size columns when rectifying dibutyl phthalate-dibutyl azelate mixtures.[f1] The following units were tested: a column with a 2 and 4-mm diameter wire spiral packing, a column with cooled and heated zones, a column with a revolving cooled rotor and heated casing, and a column with a revolving rotor turbulising both gas and liquid phases. This study demonstrated the superiority of columns of the latter type, for which the pressure drop per perfect plate was only 0.02 to 0.05 mm Hg and the HETP about 7 cm. It was also shown that with simpler designs small HETP values of about 3 cm could be obtained, but the pressure per plate would be about 0.3 mm Hg.

As indicated above, a number of research workers consider that the most suitable designs for commercial vacuum rectification are columns with tubular and plane-parallel packing. Reports have appeared on the very satisfactory operation of a column with a spiral parallel packing for batch rectification of silico-organic compounds for the manufacture of vacuum-pump oil.[f2]

In the field of molecular distillation two reviews[f3, f4] have appeared recently and a book[e6] has been published describing designs of molecular stills, vacuum pumps, instruments and other equipment of molecular-distilling plants and containing the elements of calculations for these plants. Results of tests run on a 400-mm diameter centrifugal-type still distilling cod-liver and cotton-seed oils and of experiments[f2] on the concentration of vitamins E and A and stearines in a laboratory-type apparatus with an evaporation surface area of 0.2 m² have been published.

A study of molecular distillation in a 37-step ladder-type still made of 45-mm glass tubing has been made. The authors were evidently the first to effect successfully the continuous separation of mixtures by multi-step molecular distillation.

Continuous separation of an octoil-octoil "c" mixture resulted in the practically pure components, while separation of a 50% mixture of DBP and DBA gave about 95%

DBP in the distillate and 93.6% DBA in the residue. The efficiency of the entire multi-step column was equivalent to 18.5 perfect molecular plates, while the efficiency per step was 0.5 with a length of 1.7 cm.

The effect of the pressure on the efficiency of rectification in the packing has also been investigated.[f18]

Application of Rectification to Isotope Separation

Rectification methods have found wide use for the separation of stable isotopes of hydrogen, oxygen, boron, helium, carbon and other elements. In a number of studies the separation factors for the stable isotopes of hydrogen,[g1] oxygen,[g1, g4] boron,[g2] carbon,[g3] helium[g5] and chlorine[g6] have been determined. A simple but sufficiently accurate formula has been suggested for calculating the number of plates in rectification columns operating in cascade and for systems obeying HENRY's Law.[g7]

For mixtures which obey RAOULT's Law several methods[g8, g9] for calculating separate tapped columns have been proposed. A simple graphical method[g10] for calculating columns operating in cascade has been evolved. By way of illustration, the authors employed this method to determine the cascade plant for separating nitrogen isotopes.

Equations have been suggested[g11, g12] for the rate of approach to steady state in multi-step processes for the case of rectification and chemical exchange.

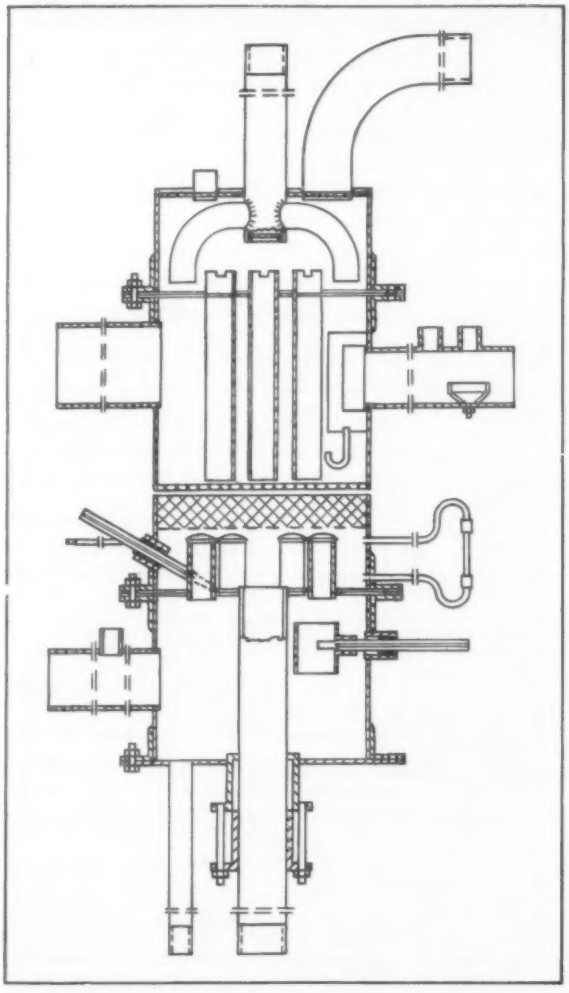

Fig. 3. Sectional view of a film-rectification column used by Fastovsky and Petrovsky for research purposes.[c19]

Several publications deal with the practice of isotope separation by rectification and chemical exchange. Packed and film-type rectification towers have been employed successfully for concentrating O^{18} to 24.5% in the rectification of water,[g13] for concentrating D_2O to 99.999% in rectifying 99.56% D_2O,[g17] for concentrating B^{10} when rectifying BF_3[g19] and BCl_3[g16] and for the preparation of He^3 concentrates.[g6] An attempt was also made[g18] to concentrate silicon isotopes by rectifying $SiCl_4$, but no perceptible separation was obtained.

A description has been given[g14, g15] of laboratory and commercial-size plants for producing N^{15} concentrates.

Rectification of Organic Mixtures

The literature published in this field characterises insufficiently the great experience gained by Soviet engineers and researchers in creation and investigation of commercial rectification processes.

An analytical method has been proposed for calculating the number of perfect plates for multi-component mixtures obeying RAOULT's Law.[h1] The distribution of the products between the bottom and distillate is determined analytically. In another publication this distribution is found for the case of complete reflux return.[h2] Closely related to these questions is an investigation of the concentration of small admixtures in absorption-desorption columns.[h3] Calculations have been made of the distribution of concentrations over the plates of the column during air rectification.[h16] Questions of reducing the steam consumption during rectification by repeated re-usage have been considered in a special monograph.[h4] The influence of the physical state of the feeding on the performance of the column was investigated.[h5]

General methods of calculating the separation of imperfect mixtures by means of *l-x* diagrams are described in monograph.[h6] A way of separating the binary azeotrope water-formic acid by rectifying at two pressures is described.[h7] Another method of separating azeotropes, by the addition of extractive agents—for instance, chlorobenzene in the case of the ethyl acetate-ethanol system or xylene in the case of a methanol-benzene mixture—has also been suggested.[h8] An example of the use of extractive distillation for weak acetic acid solutions has been described.[h9] A description is also given of the recovery of dichloroethane admixtures from drainage waters by rectification in which a heterazeotrope is formed in the distillate.[h10]

The results have been published of work carried out on the reconstruction of vacuum petroleum distillation columns,[h11, h12] as well as experience in the rectification of wood hydrolysis products,[h13, h14, h15] and in the separation of pyrolysis gases.[h17]

Books have been published on the general processes of distillation and rectification,[a1 a2] on the rectification of alcohol,[a3, a4] on the separation (mainly by rectification) of gases,[a5, a6, a8] on the manufacture of oxygen[a7] and on the application of rectification to laboratory practice.

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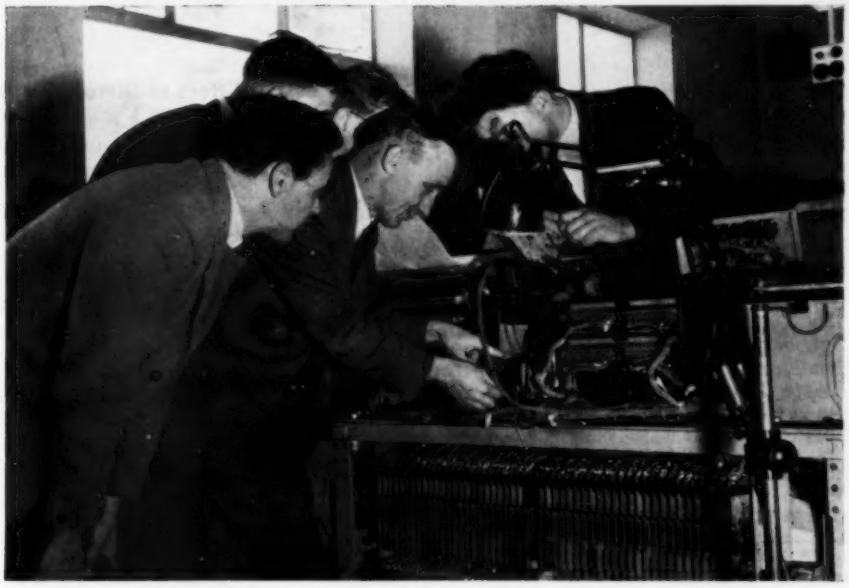

Fig. 1. Field engineers undergoing training at the British Tabulating Machine Co.'s Engineering Training School, Letchworth.

CALCULATION OF THE TRANSIENT BEHAVIOUR OF DISTILLATION COLUMNS—PART III

The accuracy of the previously-described computer-aided method of estimating plate composition* and the application to multi-component systems is discussed

by H. H. ROSENBROCK, B.Sc. (Eng.), Ph.D., A.M.I.E.E.

6. Some Examples

In order to check the programme and the method of solution, a five-plate enriching column under total reflux was considered, with $E = 1$ and the artificial equilibrium curve $y^* = x + 0.02$. The analytical solution for the composition on each plate when the feed composition is suddenly changed has been considered in some detail by Wilkinson,[4] who has confirmed the results experimentally. Five runs were made on the computer, all with $\theta = 0.5$, and with the following sets of values for the non-dimensional time-step $\delta tL/H$:

(i) 4 steps each of $\frac{1}{8}, \frac{1}{4}, \frac{1}{2}, \ldots, 16$.
(ii) 8 steps each of $\frac{1}{8}, \frac{1}{4}, \frac{1}{2}, \ldots, 8$.
(iii) 16 steps each of $\frac{1}{8}, \frac{1}{4}, \frac{1}{2}, \ldots, 4$.
(iv) 16 steps each of 1/128, 1/64, 1/32, 1/16, then
17 steps of $\frac{1}{8}$, then
16 steps of $\frac{1}{4}$.
(v) 16 steps of $\frac{1}{2}$.

The degree of accuracy achieved can be seen by comparing the results of these runs at a non-dimensional time of 6.5 with the value obtained analytically, as in Table 4.

TABLE 4—Percentage Approach to Equilibrium Calculated by Various Methods

	Plate				
	1	2	3	4	5
Run (i) ...	78.66	59.23	43.34	32.18	26.45
Run (ii) ...	78.629	59.191	43.321	32.187	26.471
Run (iii) ...	78.623	59.182	43.316	32.187	26.476
Run (iv) ...	78.621	59.180	43.314	32.188	26.478
Run (v) ...	78.64	59.20	43.33	32.19	26.47
Analytically	78.619	59.178	43.313	32.188	26.480

Run (i), which represents the calculations that would normally be made, is evidently accurate enough for all practical purposes.

The accuracy of run (v) is remarkable considering the coarseness of the steps near the beginning of the transient. The earlier values of the composition show errors up to 1.6%, and the good agreement at later times may be to some extent accidental.

Further runs were made to test the method for finding equilibrium values by using long time steps with $\theta = 1$. The following sets of values were used for the non-dimensional time-steps, and each run was made both with $\theta = 1$ and with $\theta = 0.5$:

(vi) one step each of 1, 2, 4, ..., 64.
(vii) one step each of 2, 4, 8, ..., 64.
(viii) one step each of 4, 8, 16, ..., 64.
(ix) one step each of 8, 16, 32, 64.
(x) one step each of 16, 32, 64.
(xi) one step each of 32, 64.
(xii) one step of 64.

The computed changes of composition are given in Table 5 as a percentage of the true changes.

Table 5 shows the superiority of the process with $\theta = 1$ over that with $\theta = 0.5$ for finding the equilibrium values. It also indicates that the most economical process would probably be to use three or four steps of 64 or larger. A comparison between runs (vi) and (iii) at non-dimensional times of 1 and 3, on the other hand, shows that the errors in run (vi) are less for $\theta = 0.5$ than for $\theta = 1$.

The use of a linear equilibrium curve in the problem selected for checking the computed results was dictated by the need to obtain an analytical solution. It has, how-

* *Previous parts of this article were published in the July and August issues.*

TABLE 5—Computed Changes of Composition at Equilibrium

	Plate				
	1	2	3	4	5
$\theta = 1$					
Run (vi) ...	99.74	99.51	99.32	99.18	99.10
Run (vii) ...	99.7	99.5	99.3	99.1	99.0
Run (viii) ...	99.7	99.4	99.1	99.0	98.9
Run (ix) ...	99.6	99.2	98.9	98.6	98.5
Run (x) ...	99.3	98.6	98.1	97.7	97.5
Run (xi) ...	98.4	96.9	95.7	94.8	94.4
Run (xii) ...	93.3	88.1	84.2	81.7	80.4
$\theta = 0.5$					
Run (vi) ...	100.58	99.01	100.25	99.70	99.22
Run (vii) ...	94.8	103.3	100.4	99.0	98.9
Run (viii) ...	115	96	96	99	101
Run (ix) ...	70	97	103	103	102
Run (x) ...	143	113	97	90	88
Run (xi) ...	44	74	93	105	111
Run (xii) ...	177	159	146	137	133

ever, the unfortunate result that the process of integration is not severely tested. Equation (26) represents in general a first-order process, but when $\theta = 0.5$ and the equilibrium curve is linear the process is of the second order, since $f''(x) = 0$. The point is not in practice a serious one, since if there is any doubt about the accuracy of a set of calculations it can easily be removed by repeating the calculations with smaller time-steps throughout.

The first practical use which was made of the programme was to find the start-up time and to check the equilibrium compositions of a number of columns for producing heavy water. One such calculation, for example, concerned the starting of a cascade consisting of two columns of different diameters, the first having 160 theoretical plates and the second 150. Two starting procedures were investigated:

(i) The two columns were filled with liquid having the same composition as the feed, and run without any withdrawal of bottom product until the required composition was reached in the reboiler. This occurred before the system came to equilibrium, since the columns were designed to give the required product composition with a certain take-off from the reboiler, and would therefore give a higher concentration of heavy water at equilibrium without take-off. The time required was 20.2 days.

(ii) The first column was run without take-off until the desired bottoms composition was reached. The second column was filled with product from the first column, and was then started and run without take-off until the required concentration was reached in the bottom. This took 17.7 days.

The computing time for a complete run to equilibrium was 60 min. for 160 plates and 100 min. for 310 plates. For comparison, a run to equilibrium with 5 plates took 5 minutes, and with 21 plates took 15 minutes. The equilibrium compositions for a 349-plate column (but not the approach to equilibrium) were found in 15 minutes by using time-steps of the order of 2^{15} seconds with $\theta = 1$.

The last example which will be considered is a 21-plate column with the feed on the tenth plate. Experimental results for this column, operating with a mixture of carbon tetrachloride and benzene, had been obtained by Wilkinson.[13] Starting with the computed equilibrium at total reflux, a run to equilibrium was made with a reflux ratio of 10:1. The resulting equilibrium values were then used as the starting point for a second run to equilibrium with the feed composition changed from 0.269 to 0.231. The set of calculations was then repeated with the artificial equilibrium curve $y^* = x + 0.025$. The results of these calculations have been presented elsewhere.[14]

7. Effect of Disturbances on a Column

One of the primary objects in writing the computer programme was to make possible an extensive study of the control of distillation columns. The data required for such a study are the responses of the column to disturbances of the several operating parameters. For example, in considering the effect of controlling the reflux to the column according to the temperature on a given plate, one half of the problem is to decide what valve movement will be caused by a given temperature change. The other and more difficult half is to find what changes of temperature on the given plate will be produced by a given valve movement.

A typical set of calculations for studying the control of a column is organised in the following way:

(i) Start with all the x equal to the feed composition (or with any other suitable values of x) and compute the approach to equilibrium. This calculation determines the equilibrium time and the steady-state condition of the column for the chosen operating parameters. During the course of the calculation δt will be increased as explained in Section 5.

(ii) Take the equilibrium values of x and calculate the change on every plate as the column approaches a new equilibrium corresponding to a slightly changed feed composition. The values of δt will again start from a small value and increase during the course of the calculation.

(iii) Find in the same way the response to a small change in feed rate, allowing, if necessary, for the hydrodynamic delay between a change of flow rate on one plate and the corresponding changes of flow on lower plates.

(iv) Find similarly the response to a small change of boil-up rate.

(v) Find the response to a small change of reflux.

(vi) Find the response to a change of the equilibrium curve $y^* = f(x, \vec{p})$ due to a small change in $\vec{p}$, if this effect is thought to be significant.

The programme is so arranged that this set of calculations can be carried out in one run.

It is important to notice that no linearisation of the problem has been made at this stage. If, for example, the magnitude of the change in feed composition is doubled, the computed response of the column will in general not be simply scaled up by a factor of two. The response to a small change of feed composition at one operating condition of the column will also in general be different from the response to the same change at another operating con-

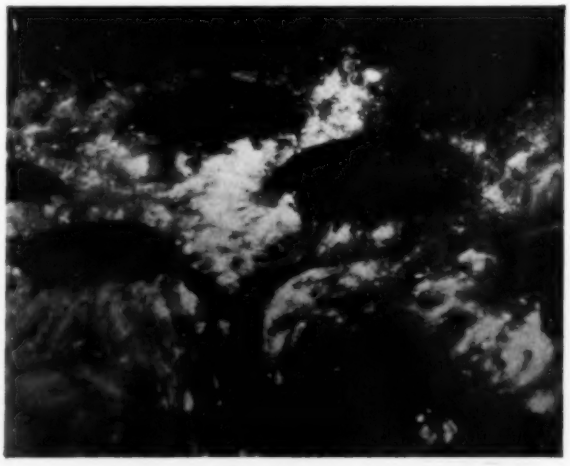

Fig. 2. Action of a bubble-cap distillation column. Digital computer-based methods give an accurate forecast of vapour-liquid composition. (Photo: Shell.)

dition. The computed results can be used to study qualitatively the effects of disturbances of any size within the operating range of the column.

For quantitative work in automatic control it is usually necessary to linearise the problem. This can be done by making the changes from equilibrium very small. For the purposes of automatic control it is also convenient to study not the response to a sudden step change of a parameter, but the response to a sinusoidal variation. The second of these can be obtained from the first (under linear conditions) by means of a graphical method.[15, 16] The result shows, for example, the amplitude and phase of the sinusoidal changes of temperature on a selected plate which would result from sinusoidal variations of feed composition having a given frequency. These are the data[17] which are required for a quantitative analysis of an automatic control scheme for a column.

It is thought that a qualitative study of the computed responses will be sufficient to decide many practical problems. A complete frequency-response analysis of some typical control schemes should, however, lead to an increased understanding of their behaviour.

8. Extension to Multi-component Systems

The published work on multi-component systems deals almost entirely with the plate-to-plate calculation[18] of the compositions at equilibrium. Such calculations are carried out, either by hand or machine,[19] by means of an approximation routine. There are, however, some difficulties in programming the routine for a digital computer, for the following reasons:

(i) If the calculation is started from the ends of the columns, some components will be effectively absent there. These components must either be introduced as the calculation proceeds, or must be included at the ends in the initial estimate with concentrations which are extremely small, e.g., 10^{-30}. The choice of the correct plate for introducing the component is not easy for the machine to make, nor will it always be easy to make a good estimate of the very small concentrations at the ends. The whole course of the solution will depend on these small estimated concentrations, which otherwise are of no interest.

(ii) If the calculation is started from the feed plate the last difficulty does not arise. It is now necessary, however, to make estimates of the composition both on the feed plate and at one end of the column. These two estimates then have to be corrected by two approximation routines, in addition to the approximation routine involved in going from plate to plate.

(iii) Corrections to the assumed compositions at the ends of the column, or at the ends and on the feed plate, are made to remove discrepancies in the material balance. When the calculations are made by hand some element of judgment is used in selecting the correction to remove a given discrepancy. It is not easy to translate this element of judgment into a mathematical formula.

On the other hand, by using essentially the same assumptions as for binary systems, it does not seem difficult to extend the transient calculations to more than two components. Whether the transient behaviour calculated in this way would represent the actual behaviour is a matter for investigation—neither practical nor theoretical work on this problem seems so far to have been done. What is interesting, however, is that the calculated equilibrium state will be identical with that obtained by the plate-to-plate calculations. Thus an extension of the existing programme to multi-component systems offers an apparently easier way of calculating equilibrium values, and may possibly also give the transient behaviour. Such an extension is at present being considered.

Fig. 3. Engineer completing final tests on the operating console of a National Elliott 405 computer. (Photo: Elliott Brothers (London) Ltd.)

9. Conclusions

From a study of the available methods for calculating the transient behaviour of distillation columns it appears that the most promising method is the use of electronic digital computers. A computer programme for binary systems is now available which gives results economically and under very general conditions. The programme has been used to study the design of distillation columns for producing heavy water, and will be used to investigate the automatic control of columns.

The programme is of such a type that it may very easily be generalised. One important generalisation which is being considered is the extension to multi-component systems.

10. Appendix.—Specification for Second Computer Programme

The second computer programme was written to the following specification:

$$y^*_r = f(x_r)$$

$$y_o = y^*_o$$

$$\left.\begin{aligned} &\text{A0}\ y_r = y^*_r,\ r=1, 2, \ldots, n+1 \\ &\text{or A1}\ y_r = E_r y^*_r + (1-E_r)\, y_{r-1},\ r=1, 2, \ldots, n+1 \end{aligned}\right\}$$

$$\frac{dx_r}{dt} = \frac{1}{H_r}\{V_{r-1}y_{r-1} - V_r y_r + L_{r+1}x_{r+1} - L_r x_r + F_r z_r\},\quad r=0, 1, \ldots, n-1$$

$$\left.\begin{aligned} &\text{B0}\ \frac{dx_n}{dt} = \frac{1}{H_n}\{V_{n-1}y_{n-1} - V_n y_n + L_{n+1}X_{n+1} - L_n x_n + F_n z_n\} \\ &\frac{dx_{n+1}}{dt} = \frac{1}{H_{n+1}}\{V_n y_n - V_{n+1}y_{n+1} + L_{n+2}x_{n+2} - L_{n+1}x_{n+1} + F_{n+1}z_{n+1}\} \\ &\text{or B1}\ \frac{dx_n}{dt} = \frac{1}{H_n}\{V_{n-1}y_{n-1} - V_n y_n + L_{n+1}Y_n - L_n x_n + F_n z_n\} \end{aligned}\right\}$$

$$\left.\begin{aligned} &\text{C0}\ X_{n+1} = x_{n+1}\ [\text{or } Y_n = y_n] \\ &\text{or C1}\ X_{n+1}(t) = x_{n+1}(t-\tau)\ [\text{or } Y_n(t) = y_n(t-\tau)] \\ &\text{where } x_{n+1}\ (t-\tau)\ [\text{or } y_n\ (t-\tau)] \text{ is obtained by linear interpolation between the two nearest stored values of } x_{n+1}[\text{or } y_n] \end{aligned}\right\}$$

$$
\begin{aligned}
\delta t &= c_1, && 0 \leqslant t < m_1c_1 \\
&= c_2, && m_1c_1 \leqslant t < m_1c_1 + m_2c_2 \\
&\text{---------- etc. ----------} \\
&= c_k, && m_1c_1 + m_2c_2 + \ldots + m_{k-1}c_{k-1} \leqslant t < m_1c_1 + m_2c_2 + \ldots + m_kc_k
\end{aligned}
$$

$$F_r = 0, \; r \neq s$$

D0 F_r, z_r, H_r, L_r and V_r are independent of t

or D1
$$
\begin{aligned}
F_s(t) &= F_s, \; t < f_s & z_s(t) &= z_s, \; t < Z_s \\
&= F'_s, \; f_s \leqslant t & &= z'_s, \; Z_s \leqslant t \\
H_r(t) &= H_r, \; t < h_r & L_r(t) &= L_r, \; t < l_r \\
&= H'_r, \; h_r \leqslant t < h'_r & &= L'_r, \; l_r \leqslant t < l'_r \\
&= H''_r, \; h'_r \leqslant t \\
V_r(t) &= V_r, \; t < v_r \\
&= V'_r, \; v_r \leqslant t < v'_r \\
&= V''_r, \; v'_r \leqslant t.
\end{aligned}
$$

Punch out every $x_r(t)$ for specified values of t (every pth time-step)
Print out $x_r(t)$ for $r = r_1, r_2, \ldots$ and for specified values of t
Stop when

E0 $m_1c_1 + m_2c_2 + \ldots + m_{k-q}c_{k-q} \leqslant t < m_1c_1 + m_2c_2 + \ldots + m_kc_k$
and no $|\delta x| > \eta$

or E1 $t = m_1c_1 + m_2c_2 + \ldots + m_kc_k$

ACKNOWLEDGMENTS

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Geigy's Two Centuries of Growth

From dye and drug merchants to a world-wide manufacturing network

IN 1758, Johann Rudolf Geigy, founder of the Geigy organisation, set up in business as a merchant of dyes and drugs in Basle, and from that modest beginning has grown over the past 200 years a network of some 50 chemical companies operating in over 17 countries. A direct descendant of the founder still serves on the organisation's board.

As early as 1833 the business operated its own water-driven dyewood mill at Basle. In the middle of the nineteenth century, the founder's great-grandson built a steam-powered dye extract works in the town and there he later made synthetic dyes, so completing a transition in the firm's activities from merchanting to large-scale chemical manufacture. The firm was, in fact, one of the first anywhere to manufacture synthetic dyes, for it started in 1859 with magenta (fuchsine) only three years after W. H. Perkin's discovery of mauve. It flourished as a supplier of dyes to the rapidly-expanding Swiss textile industry, and its interests quickly spread abroad. In 1846 43 representatives in Western and Central Europe were on its books, and several of those early agencies developed into associate companies, among them the British, which dates from 1886.

Although it was in the dyeing industry that Geigy was best known up to the last war, the elaboration of DDT insecticide in the Basle laboratories spread its name throughout the world. The work was the outcome of a research programme started in the 1920s with the purpose of developing a permanent mothproof for wool.

In Britain the organisation has specialised in plastics chemicals and it operates in a group of companies comprising Geigy (Holdings) Ltd., with headquarters at Rhodes, Middleton, near Manchester, and the following operational companies: selling companies, The Geigy Co. Ltd., Rhodes, and Geigy Pharmaceutical Co. Ltd., Wythenshawe, Manchester; manufacturing companies, Ashburton Chemical Works Ltd., Trafford Park, Manchester, and James Anderson & Co. (Colours) Ltd., Paisley; research and development companies, Aliphatic Research Ltd. and Gyl Chemicals Ltd. The British group is the second largest in the Geigy organisation and the parent company in Basle is, moreover, joint owner, with Ciba and Sandoz, of the Clayton Aniline Co. Ltd., Manchester.

Other products of the factories include auxiliary chemicals and preparations for the textile industry. The manufacture of organic pigments has been expanded by the installation at the James Anderson's works of new plant for the production of phthalocyanine colours, and, in the field of pesticides, Geigy and Fisons are now collaborating on a world basis in research, development and distribution. The Geigy organisation was the first to manufacture sebacic acid in Europe, a starting material for sebacate plasticisers and lubricants for jet aircraft engines, and in March of this year the completion of extensions to the plant in Manchester were announced which are designed to increase output of this material by 40%. Among a range of other products for special application are chelating (sequestering) and wetting agents, and investigations are at present being undertaken on organic chemicals for metal treatment and for use in the production of rare metals. In pharmaceuticals in Britain the organisation has concentrated on the development of barbiturates.

In America, the agency set up in New York in the 1870s was transformed into a company in 1903, and today the Geigy Chemical Corporation, with headquarters in Ardsley, New York, controls two factories, one in McIntosh, Alabama, and the other in Cranston, near Providence. The French factory at Huningue, near the Swiss border, was established in 1923 and it is now under the control of the Paris headquarters of the French companies formed during and after the Second World War. Other associates with the parent company are established in Spain, Italy, Austria, Sweden, Holland, Portugal, Canada, Brazil, Argentina, India, Australia, South Africa, Hong Kong and elsewhere, and the world-wide Geigy group now employs some 8000 persons.

METHODS OF ORGANISING CHEMICAL ENGINEERING PROJECTS

Three forms of organisation are described, one applicable to very large projects and the other two to smaller projects undertaken by either a chemical manufacturer or a contractor*

The Organisation of Chemical Engineering Construction Projects

by Sir Leonard Owen and C. J. Turner ([U.K.A.E.A.] Industrial Group H.Q.)

THE ORGANISATION for the engineering of a chemical plant associated with atomic energy production is headed by an engineering director with two deputy directors. One such director has under his control electrical and instrument engineering, estimating, progress and the buying departments. The other is responsible for architectural work, structural, constructional and civil engineering. At the centre of the organisation stands the project engineer with direct responsibility to the director of engineering, and with what might be termed lines of communication to the electrical and instrument engineer on the one hand and to the architectural and structural and civil engineer on the other.

The first task of the project engineer is to develop the basic scheme of manufacture once he has been provided with the requisite information by the research and development branch. The project engineer will then produce a general scheme, including the plant layout in which the foremost consideration is the control of the process; the combating of hazards and the provision of maintenance facilities are other important points of concentration. The next step is to develop the scheme in sufficient detail for actual work on the plant to start. At the project engineer's disposal for this development of the scheme are the design teams consisting of a design engineer and a number of draughtsmen. Preparing detailed specifications and working drawings of individual items of plant as well as layout and pipework drawings are the tasks of the design team. In the case of the Dounreay Fast Reactor project, for example, relating to a section of the entire plant, one design team dealt with the detailing of the equipment for the fuel element plant, another with the heavy chemical extraction plant, and so on.

At this same stage the process engineer will specify the operating conditions for the electrical equipment, where it is to be located, and, in fact, give the electrical engineer all the information necessary to enable him to prepare specifications for ordering this equipment and the layout drawings of the electrical installations. Similar considerations apply to instrumentation where the instrument engineer will prepare from the project engineer's flow-sheet a list of instruments and automatic control devices. From this schedule, which is agreed with the project engineer, a specification will be prepared and any necessary design work will be started.

A scene from the recent Chemical and Petroleum Engineering Exhibition—the occasion of the Project Organisation Symposium.

To assist him with unusual design work or other problems requiring specialised treatment, the project engineer is flanked on the one side by an experienced chemist-chemical engineer, and on the other by a technical engineer. The former advises the project engineer on chemical engineering and operational aspects of the processes. For problems requiring for their solution a profound mathematical approach, the project engineer can turn to the technical engineer, who is especially skilled academically.

Once the main features of the plant are fixed, the pro-

* *Presented to the Joint Symposium on the Organisation of Chemical Engineering Projects, organised by the Institution of Chemical Engineers and the Institute of Petroleum, June 24 to 26, 1958, at Olympia.*

ject engineer provides the architect, who is to be found in one of the three main branches of the organisation, with such information as weights of vessels to enable the design of buildings to proceed. The civil engineer, also in this wing of the organisation, prepares the layout for the entire factory inclusive of process buildings, whose specifications would already have been prepared by the project engineer. Included in this layout will be workshops, canteens and offices, whose details will already have been agreed by the factory manager, architect and project engineer.

Two contracting departments directly responsible to a director of accounts, who is himself responsible to the project engineer, attend to contracts for equipment and for erection and constructional work. Liaison with buying departments and the quantity surveyor assists in this work, and lump-sum contracts are utilised wherever possible.

A construction engineer, aided by a resident engineer and staff, supervises site work and is responsible for its quality and for the fulfilment of completion dates. Subordinate also to the construction engineer is a planning engineer who schedules the entire work of the project, including design work.

The engineering organisation comprises three main branches; the construction engineer and those closely allied with him are to be found in one branch and linked with, but not controlled by, the project engineer. On the other side of the project engineer's branch is a further branch for electrical and instrument engineering which contains also those sections interested in the financial control of the project. Included here are the buying department already mentioned, the progress and inspection sections, and the estimating and sanctions engineers. One of the functions of this latter section is to prepare a detailed estimate once the general design has been fixed; the project engineer co-ordinates the estimates and sees that they are correct and complete. With his specialist designers, he must ensure that the expenditure does not exceed the sanctioned figure.

A problem which may beset the project engineer earlier on is that some of the information with which he is provided may be conflicting. A design committee has the function of resolving difficulties of this kind and of directing applied research into the most useful channels. Another committee attends to the progress of the project and both committees are under the chairmanship of the director of engineering.

Not unexpectedly, this paper drew forth a number of questions and criticisms. Who called a halt to the design work; why was more use not made of models; and why were the plants always surrounded by buildings, were some of the questions raised by MR. DUGDALE-BRADLEY (Shell Chemical Co.). He also raised queries about the length of time for completing a project—five years was the figure given in the paper—the apparent separation between maintenance and construction, and the overlapping in functions between technical, design and buying engineers. How much money would the project engineer be allowed to handle, and his relation to research, were other questions put to the authors.

Doubts were expressed by E. W. RODNIGHT (B.O.C.) about the freedom of the project engineer to take correct decisions and to co-ordinate the various aspects of the work in view of the mass of detail he had to handle. It seemed difficult also to see how the project engineer could be responsible for the technical design as well as the engineering design when he had one chemical adviser only; the degree of control exercised by the research and development departments upon the process engineering schemes and the plant diagrams ought also to be known.

The authors of the paper were also asked to justify the project engineer's responsibility for keeping the expenditure within the allotted sum, despite the fact that departments such as estimation and construction were not under his direct control.

Another critic, who thought the term project engineer a misnomer, wanted to know how soon in the life of the project the operating staff were trained and what sort of a person the project engineer was.

SIR LEONARD OWEN, replying to the discussion and questions, considered five years for the completion of a project to be reasonable and the separation of maintenance and construction was customary within the authority. (*The question seems to have been misunderstood.—Ed.*) The cost of a project under the control of the project engineer could be of the order of £40 million. Admitted was the practice of putting plants in buildings, but there is now a tendency to put more plant in the open. However, he said, the authority could do more in this direction. Models are used but they were of the architectural type and their purpose was to acquaint "one's betters" with the project. Buying engineers and design engineers have quite distinct functions. The former, provided with data from the design side, prepares the buying specification, a function which the design engineer would not be expert enough to undertake.

The partial answer to MR. RODNIGHT'S point was that the flow-sheeting is done by the research and development branch, and this is interpreted by the chemical engineer or the project engineer's staff. MR. G. F. DUTTON (Petrochemicals Ltd.) did not receive a direct reply to his point, although it was pointed out that closer liaison exists between the project engineer and other sections not directly under his control than perhaps the paper actually stated. For example, in the case of the architectural and civil engineering work, a deputy to the engineering director was in charge and worked closely with the project engineer. The project engineer himself was primarily a mechanical engineer with a broad knowledge of chemical engineering; as for the operating staff, they were appointed early on. The man elected to be in charge of the operation would also be appointed at an early stage and would be in contact with the designers for considerable periods and would prepare the operating manuals along with the design people.

A System of Project Organisation

by R. E. Bywater (Simon-Carves Ltd.)

MR. BYWATER'S PAPER dealt with the organisation used by a contractor to build a plant to his own design. The responsibility for executing the project rests with the contracts engineer, who is subordinate to the chief contracts engineer. When an order has been accepted, the appointment of the contracts engineer is one of the first steps to be taken; he has to co-ordinate every aspect of the work.

A construction programme produced by the planning engineer forms the basis for the drawing and purchasing programmes. The drawing office hours are thus fixed and a progress chart kept of the draughting work. The project engineer has to see that all special conditions, including tests and inspections, are specified in the inquiries and orders sent to the sub-contractors. The contract engineer will have to acquaint the various specialist departments within the contracting firm of the main features of their individual parts of the project.

It is a good plan to place orders early on for the long-delivery items, leaving the detail for completion at a later date. Arrangements can be made with sub-contractors for ordering structural-steel plate and castings, so that manufacture need not be held up for want of material.

In the drawing office, which plays a role of outstanding importance, the aim is to finish the layout as soon as possible and to fix the foundation-loading plan to enable

work to begin on reinforced concrete design. Soil-loading capacity at the site must be known—here the local authority might prove useful—and a number of other points have to be discussed with the client, such as effluent disposal and future development.

Financial control over purchasing is exercised by passing requisitions from a semi-technical buyer through the estimating office. If expenditure on a piece of equipment has to exceed the original allowance, it has to be sanctioned. Moreover, while work on the project is on the move the contractor must know how the expenditure is running and how actual progress compares with the planned aim. For this latter reason monthly totals of expenditure embracing every aspect of the job are sent to the chief engineer.

Close working between the buying section and the progress and inspection sections is desirable, not only because it prevents orders going to firms guilty in the past of shoddy workmanship, but also because it avoids deluging any one sub-contractor with too much work. Other important features of the organisation are the progress meetings held to check the progress of design, purchasing, material deliveries and erection. Through these meetings action can be taken to overcome obstacles tending to delay completion of the project. Spare parts also have to be considered; in some cases it may be necessary to have a year's supply in hand when plant is commissioned. Again, the progress and inspection of plant and materials required their section of the organisation which, armed with purchase orders, would be able to "chase" the work of the sub-contractors. Inspection engineers attend to the inspection of fabricated equipment and the results are communicated to the contract engineer.

Described also were the functions of the site engineer and the commissioning staff, while the need to acquaint the client's maintenance force with the plant was touched upon.

Before the contract is settled, the effect of design modifications has to be taken into account. Therefore, an early understanding must be reached with the client about the adjustment of the contract price to meet such changes. As a result, they have to be carefully recorded by the contractor and the price of each amendment agreed.

Systems of Project Organisation

by K. M. Curwen (Albright & Wilson Ltd., Oldbury)

The organisation which a chemical manufacturer would use to carry out a project was described by MR. CURWEN (Albright & Wilson Ltd., Oldbury). The work of a project may be divided into two parts: that of process and project engineering. The work of the former is that of producing the chemical-engineering flow diagram and includes studies of existing processes and pilot-scale work. The field of project engineering, which is concerned with work already authorised, is the detailed mechanical- and chemical-engineering design and the demarcation line between the two is often the director's authorisation to proceed with a project.

This paper was limited to the two types of project where, in the first case, the manufacturing company carries through with its own resources the entire project, and, in the second case, where the company does all the design, provides supervision of construction, but uses a contractor for the contructional work.

Three types of organisation to deal with these two cases were described. The source of projects would be the company's research department, an outside company when a process is to be operated under licence, or from the production department when the latter requires additional capacity for an existing process. In each of these types of organisation the proposal is examined by the process-engineering section, as this measure makes it possible to include improvements.

The preferred system of organisation has the managing director at its head with two branches under his direct control: the buying section and the engineering section headed by the chief engineer. In this system the chief engineer and the chief buyer are directly responsible to the managing director. The project and process engineering, as well as planning, estimating and electrical engineering, are under the control of the chief engineer. Responsibility is so subdivided that the project engineers are responsible for the draughting and civil engineering work. Instrument and project evaluation, on the other hand, are the responsibility of the process-engineering department.

When a proposal is first put forward a preliminary account of its economies is submitted to the board of directors. This early evaluation reduces the chances of wasting detail design work on an uneconomic process. Once approved, the organisation of the project engineer is set in motion to produce the process-design report, which includes the chemical-engineering flow sheet. This report will contain a more detailed account of the cost of the product and plant.

Urgency of a project sometimes leads to detailed design being undertaken before the basic process design is complete. This practice ought to be avoided whenever possible, since it reduces the output of work from an engineering department. Long-delivery equipment, however, should be ordered at an earlier stage.

The usefulness of models was stressed. The author had found a method wherein two models were used to be very satisfactory. The first model (1/48 scale) was made during the later stages of the project engineering as an aid to the general layout. The second, a 1/24 scale model, was used for detail design (including pipework), erection and training. Models had also proved useful in preparing material lists and three-dimensional drawings were found not to be required. The model costs were of the order of 1% of the total cost of the plant.

Once the go-ahead has been given, a schedule is prepared giving the required times for completing the different sections of the report. When the design work has reached finality, another schedule is prepared which states the dates by which individual pieces of equipment are to be delivered; a further schedule embraces the erection work.

The economic drafting force for a £100,000 project was about three draughtsmen plus a section leader. If the project was a complex one, the number of draughtsmen might be increased by one or two.

Installation costs quoted in the authorisation estimate will be a guess based upon past experience. Therefore, a contingency allowance has to be used which is fixed according to the nature of this experience. This allowance, which is meant to cover uncertainties in erection conditions and site preparation, is placed under the control of the chief project engineer to prevent it being spent simultaneously by separate branches of the project team.

Working directly for the project engineer is a site engineer, whose job it is to see that the various pieces of equipment arrive at the site according to plan and, where appropriate, are tested mechanically; site meetings are held at the behest of the project engineer, whose other responsibilities include the training of the plant manager and the operating labour force before mechanical testing is completed. During the commissioning period skilled operators are necessary; a good idea is to use young men from the design staff for this purpose.

The discussion on the papers presented by Mr. Bywater and Mr. Curwen will be given in the October issue.

66.048.2

DROPWISE CONDENSATION IN EVAPORATORS*

An account of some plant-scale experiments on dropwise condensation of steam in evaporator heaters

by DONALD E. GARRETT, B.S., Ph.D., A.I.Ch.E.

THE use of additives to promote dropwise condensation in vapour-liquid heat exchangers has been studied for many years. The results of these laboratory tests have indicated that the steam-film coefficient may be increased as much as tenfold when dropwise rather than film-type condensation takes place. This has raised the possibility that the overall heat-transfer coefficient in certain industrial heaters might likewise be increased by the addition of the promoter to the steam.

The potential profitability of realising even a few per cent increased capacity in the large brine evaporators of the American Potash & Chemical Corporation's plant was sufficient to warrant a thorough study of dropwise condensation. (These units evaporate more than 3 million gallons of brine a day.) Such a study has been conducted in the form of pilot-plant screening tests, a single-plant heater test and, finally, a comprehensive one-year plant test.

Unfortunately, the industrial application was entirely unsuccessful. The monitoring methods should have been able to detect a 5% capacity increase easily, and a 2% increase reasonably well. No increase was noted. The pilot-plant tests indicated that a 30% increase in capacity was possible. Tubes removed from the plant heaters following the plant test, and then tested in the pilot unit, indicated that perhaps half the indicated gain should have been effected, for they showed excellent dropwise condensation. The best explanation for this failure is that: (1) the "dirty" tubes, under the contaminated plant steam conditions, gave a much smaller heat-transfer improvement than would new tubes; and (2) the showering of condensate on tubes throughout the heater bundle was of a sufficient magnitude to overpower the potential dropwise or non-wetting effect. This was very likely partly a result of the aged, rough surface of the tubes. The filming agent did reduce the scaling (corrosion) rate of the tubes to some extent, and greatly reduced the corrosion rate in the condensate system.

* **Editor's Footnote:** *When we first heard that the American Potash & Chemical Corporation, Trona, California, were investigating dropwise condensation on a plant scale, we approached them for an article on this interesting topic. We were informed by Mr. Garrett that their work to date had not proved successful, but if we were still interested he would write us an account of the experiments. In view of the interest in promoting dropwise condensation and the lack of data on plant-scale experiments we considered that such an article would be of value, despite its negative results.*

Dr. Garrett *obtained his degree of B.S. in chemistry from the University of California in 1947. He took his Ph.D. in chemical engineering at the Ohio State University in 1950. He has worked with the U.S. Atomic Energy Commission, with Dow and with Union Oil, and is at present research manager of the American Potash & Chemical Corporation.*

Relevant Literature

Laboratory or single-tube studies on dropwise condensation have been extensively reported, and several texts[1] and articles[2] give a detailed account of the phenomenon. When vapours condense on a surface that they do not wet, the liquid forms small drops rather than an even film. Since the liquid film acts as an insulating layer, the presence of drops means that a fraction of the surface is always exposed, and consequently a higher heat-transfer rate results. As the drops fall they grow in size and sweep an even greater area free of condensate. To partially compensate for this smaller area covered by the condensate film, the thickness of the promoter in itself acts as an insulator. To be effective, therefore, the film must be thin;

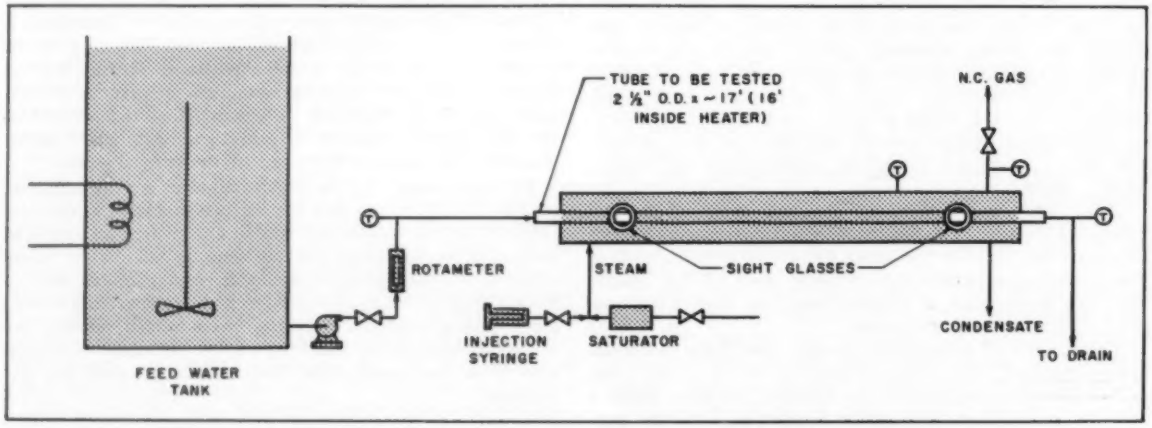


Fig. 1. Single-tube heat exchanger set up for pilot tests on dropwise condensation.

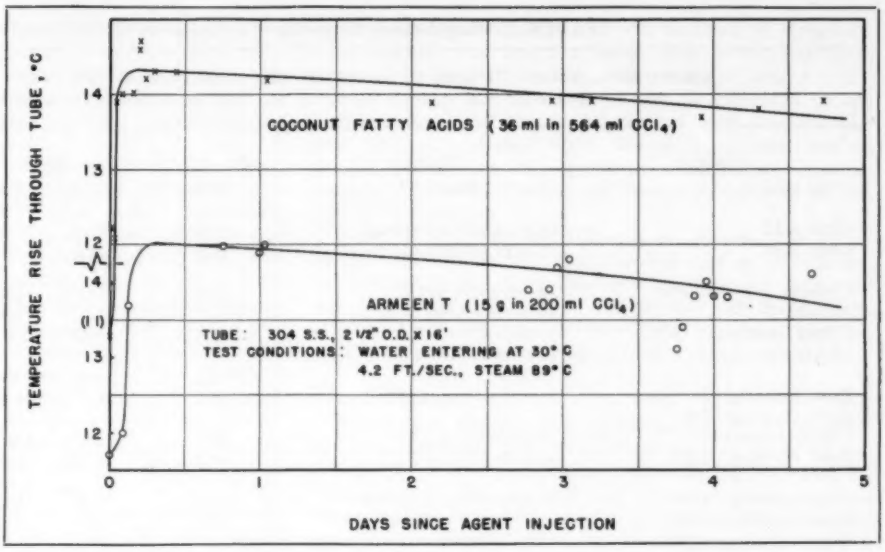

TEMPERATURE RISE THROUGH TUBE, °C
COCONUT FATTY ACIDS (36 ml in 564 ml CCl_4)
ARMEEN T (15 g in 200 ml CCl_4)
TUBE: 304 S.S., 2 1/2" O.D. x 16'
TEST CONDITIONS: WATER ENTERING AT 30° C
4.2 FT./SEC., STEAM 89° C
DAYS SINCE AGENT INJECTION

Fig. 2. Lasting power of various dropwise condensation agents.

preferably only a few molecules. This implies that the promoter or filming agent should contain heteropolar groups, one part to give it an affinity for the heat-transfer surface, and the other to prevent the condensing vapours from wetting it or the surface. Functional groups such as amines, acids, mercaptans, etc., can be used to form the metal bond. When steam is the condensing vapour, the other part of the molecule is generally an alkyl or aryl group to provide the desired hydrophobic characteristics. The film may be formed on the surface either by injecting the agent into the vapour or by manually coating the tube.

Many agents have been tested for their filming characteristics. Lubricating oil has been observed to promote dropwise condensation with steam under certain conditions. If applied to a new, clean tube, complete drop formation will occur for a short time until the coating is washed off. Likewise, it may be injected with the steam on to a clean tube to promote partial dropwise condensation. However, the effect is a transitory one and will not be noted on older or scaled tubes. This phenomenon has often been reported for polished tubes, where even minute traces of oils will promote dropwise condensation. Again, however, the effect is a transitory one and will not survive the washing away of the film or contamination of the surface.

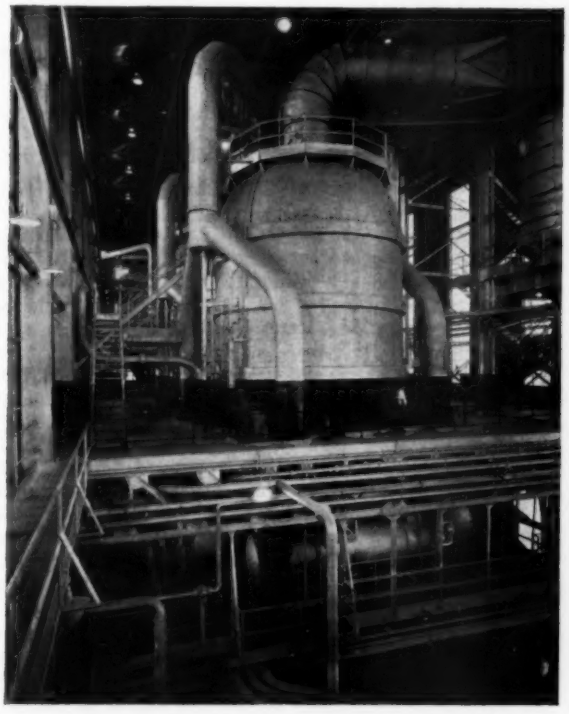


Fig. 3. First effect of evaporator unit where some dropwise promotion experiments were carried out.

Specific additives for special metals, additives such as mercaptans (e.g., benzyl mercaptan) or thiocyanates (e.g., octyl thiocyanate) for copper or copper alloys, have been reported to give excellent results and to have great tenacity.[3, 4] Other investigators have reported on the use of more general agents such as fatty acids,[5, 6] long-chain amines[7] and silicones,[8] which also gave excellent results with a variety of metals. With vapours other than steam, favourable results have been achieved with coatings of tetrafluorethylene polymer.[9] In these examples of the many laboratory studies that have been made, steam-film coefficients ranged all the way from 3000 for "dirty", unfiltered steam, to values approaching 100,000. This represents an increase in the steam-film coefficient of from about four to ten times the value for filmwise condensation.

Unfortunately, almost none of the studies on dropwise condensation has been brought to an industrial test. One exception is work done on steam-heated paper (pulp) driers.[7] When octadecylamine was added to the steam entering these large drums, it was found that the capacity was increased from 2 to 15%. The smaller of these improvements would require the steam-film coefficient to be from 2000 to 4000; the larger increase would require an extremely large coefficient.

A second brief reference[10] mentions industrial tests where the vapours to a marine condenser and a power station condenser were treated. With the latter unit "... the action of the promoter film was hindered by rust and the effect of air ... (in the vapours)". Apparently, in the former test, the results were satisfactory.

An associated phenomenon that has been widely tested industrially is the use of many of the same filming agents as corrosion inhibitors and cleaners in heating systems. Materials such as octadecylamine have been reported[11, 12] to cut down condensate-return-line corrosion by as much as 95%. The mechanism reported is that the polar part

TABLE 1—Single-tube, Dropwise Condensation (DWC) Tests

Steam: 89°C. Water: 72 gpm (5 ft/sec.) at inlet temperature of 30°C. New sanded tube, 18 BWG, 304 stainless steel, 2½ in. OD, 16 ft long (in heater)

Additive	*Quantity*	*Base* Δt	*Max.* Δt	*Remarks*
Oleic acid	15 cc in 500 cc CCl_4	10.5	12.9	Complete DWC. Rapid decline (11.7 in 5 hr)
Oleic acid	15 cc in 500 cc butanol	10.3	11.4	DWC for very short time
Oleic acid	15 cc in 500 cc benzene	10.3	12.0	DWC. Rapid decline (11.2 in 4 hr)
Coconut oil—Armour	30 ml in 470 ml CCl_4	10.5	14.7*	100% DWC
Armeen T	30 gm in 470 ml CCl_4	11.7	14.5*	100% DWC
Ethylpolysiloxane X-12	15 cc in 475 cc CCl_4	10.8	10.8	No effect
Ethylpolysiloxane X-12	15 cc in 475 cc 50-50 CCl_4-CH_3OH	10.8	10.8	No effect
Dow Corning pan glaze	30 ml in 470 cc CCl_4	10.1	10.7	∼10% DWC for short time
Dow Corning—200 (100 centistoke)	30 ml in 470 cc CCl_4	10.5	11.1	Same as above
Dow Corning—1107	30 cc in 470 cc CCl_4	10.5	11.2	∼10 to 15% DWC for very short time
Dow Corning—1107	30 cc in 470 cc C_4H_9OH	10.5	11.4	Same as above
Dow Corning—1107	20 cc in 480 cc $C_8H_{17}OH$	10.5	11.1	Same as above
Dow Corning—1107	15 cc in 480 cc methyl-ethyl ketone	10.5	11.3	Same as above
Phenoltrichlorosilane	30 ml in 470 cc CCl_4	10.2	10.7	∼10% DWC for short time
Dimethyldichlorosilane	30 cc in 470 cc xylene	10.5	11.0	∼10 to 15% DWC for very short time
Dimethyldichlorosilane	30 cc in 470 cc 50-50 CCl_4-C_4H_9OH	10.5	11.0	Same as above
Dimethyldichlorosilane	Tube exposed to air-silane vapours 20 min.	10.5	12.6	∼30% DWC for short time
Dimethyldichlorosilane	30 ml in 470 cc CCl_4	10.1	10.3	Very little DWC
Dimethyldichlorosilane	Tube swabbed with 10% soln. in CCl_4	10.5	11.0	∼5% DWC for short time
Dimethyldichlorosilane	Swabbed on tube	10.5	9.6*	10% DWC
Permacol (series 110)	30 cc in 470 cc H_2O	10.5	13.5	DWC. Moderate decline (12.9 in 24 hr)
Permacol (series 110)	15 cc in 250 cc 50-50 CCl_4-C_6H_6	10.5	13.6	Same as above
Permacol	Intermittent addition for 8 days. Used tube: 5 yr. 5 mos. in Heater 23, 14 g. lead - sprayed Admiralty (slightly different test conditions)	11.3	13.4	∼50% DWC at first, then reaching ∼95% after sixth day
Permacol	Similar test, but with water at 79°C and at 58 gpm	4.8	6.4	Same as above, on first day

* Test conditions the same, except water flow at 57 gpm.

of the molecule attaches itself tenaciously to the metal or the corrosion coating on the metal, and will eventually even cause considerable sloughing off of the scale. The surface is then insulated from further attack and corrosion. The thinness of the layer and the tenacity of the bond are such that the presence of considerable CO_2 or H_2S in the steam does not prevent the agent's effectiveness or cause excessive consumption of it. These materials are frequently added to the vapours prior to the condensing surface, and thus should also act as dropwise condensation promoters. However, among the many testimonials for their effectiveness as corrosion inhibitors, with the exception of one reference,[7] no mention has been made of a parallel improved heat-transfer performance.

Laboratory Tests

In the very favourable light of the literature on the subject, it was felt that the potential of dropwise condensation was sufficient to warrant tests to determine its industrial practicality. The application of dropwise condensation to the brine evaporators of the American Potash's Trona plant, with their tremendous capacity, could be very profitable if even a small increase in the heat-transfer rate were accomplished. The heaters of these evaporators were therefore the object of this study.

The equipment used for the first, or screening, tests is shown in Fig. 1. It consisted of a single-tube heater accommodating a full-size evaporator heater tube. Two sight glasses were placed in the shell so that the tube could be observed, and suitable attachments were made so that various additives could be injected into the steam. A wide range of temperatures and velocities was available, but, in general, the tests were made at standard conditions simulating one of the effects of the brine evaporators. Both stainless-steel (304) and Admiralty tubes were used. Usually the tube was scrupulously cleaned before a test, but in two runs a tube that had been in service for four years was used. The cleaning procedure was to give the tube a light sanding, then to wash it successively in carbon tetrachloride, acetone, and finally water. The injection equipment was given a similar wash to ensure that the last traces of each additive were removed.

The filmwise condensation performance of the tube was checked at the beginning of each run to test the cleanness of the surface, and thus the consistency of the test conditions. To simplify comparison of the various additives, the heat-transfer rate was recorded merely as the temperature rise of the water through the tube. Since all

other conditions were held constant (for most of the tests), this $\triangle t$ can readily be converted into a heat-transfer coefficient, if desired. However, for the purposes of these tests the ratio of a given temperature rise to the filmwise $\triangle t$ is a suitably close approximation of the increase in the heat-transfer coefficient.

Table 1 gives a summary of the results of these tests. It would appear that the fatty acids and Permacol (octadecylamine) were very effective and had a reasonable sticking power. In most of the tests the additive was injected into the steam at the beginning of the run only, and then the performance watched for the next eight hours to five days. In most cases there was, following the injection, an immediate lowering of the coefficient which lasted from ten minutes to an hour. Then the coefficient would increase to a maximum and slowly taper off. Fig. 2 shows typical examples of the results obtained. A visual observation of condensation was also very useful in understanding and appraising the results of the tests, for differences in performance were graphic. Following the injection of the agent, an oily layer was present on the tube, and it was not until this disappeared that the heat-transfer rate increased. The drops during the period of the maximum rate were comparatively small, evenly spaced, and rolled off the tube very rapidly. As the heat-transfer rate began to decrease, the drops became progressively larger, more sluggish, and less uniformly spaced and sized on the tube. Even though the dropwise condensation still appeared to be reasonably complete, the tube area covered by condensate was obviously constantly increasing as time went on.

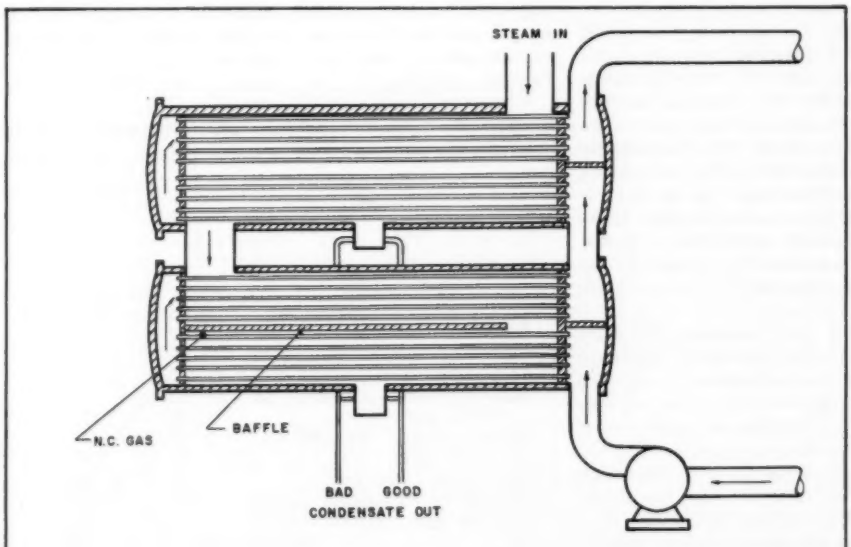
The tests on old and scaly tubes showed somewhat different results. Following the first injection of Permacol, only about 50% of the tube showed dropwise condensation. The top of the tube gave better performance than the sides and the drops were very large and sluggish. With each new injection of Permacol the performance improved, and by the sixth day the dropwise condensation was essentially complete. Following a shut-down of the unit for a week-end, the coefficient, and the amount of dropwise condensation, was low for about four hours and then returned to its previous high value without further addition of Permacol. This could perhaps be explained by air having entered the system. A later test with a second old tube, but at a higher water temperature, gave similar results. Here, however, dropwise condensation became complete following the second Permacol addition at the end of the first day.

None of the tests on silicones or silanes gave good results (with the method of application used in these tests). A direct swabbing of the tube or a condensation on a wet tube, as specified in one of the silicone references,[8] was attempted with dimethyldichlorosilane, but even then the results were only partially successful.

Plant Tests

Based upon the encouraging laboratory results, a plant test was scheduled. Fig. 3 illustrates the first effect of the plant's No. 3 brine evaporator unit, and Fig. 4 is one of the heaters. It was decided that the most useful, and at the same time the most severe test of the filming agent would be to apply it in the vapours going to the second and third effects. This was done as shown in Fig. 5. There were a number of conditions present in these heaters that involved uncertainties from the laboratory tests. First, many of the tubes were older and even more scaly than those previously tested. Secondly, some brine entrainment with the steam is unavoidable, so the average condensate is basic and comparatively high in dissolved solids. Finally, the amount of non-condensables is comparatively high. Some H_2S and CO_2 are given off from the brine, and some air leaks are unavoidable in a unit of this size and complexity.

Table 2 lists vent gas and condensate analyses that are reasonably typical, but wide fluctuations can be expected to occur regularly. Because of the high H_2S content the heater tubes tend to corrode rapidly. At present all of the second- and third-effect tubes are Admiralty metal,



EFFECT	TUBES PER HEATER	CONDENSING AREA PER HEATER, SQ.FT.	VELOCITY IN TUBES, FT/SEC	AVERAGE HEAT TRANSFER COEFFICIENT BTU/(HR)(SQ.FT.)(°F)
2 ND	264	3922	4.8	505
3 RD	264	3922	4.9	325

Fig. 4. Diagram showing design of evaporator heaters used in the trials.

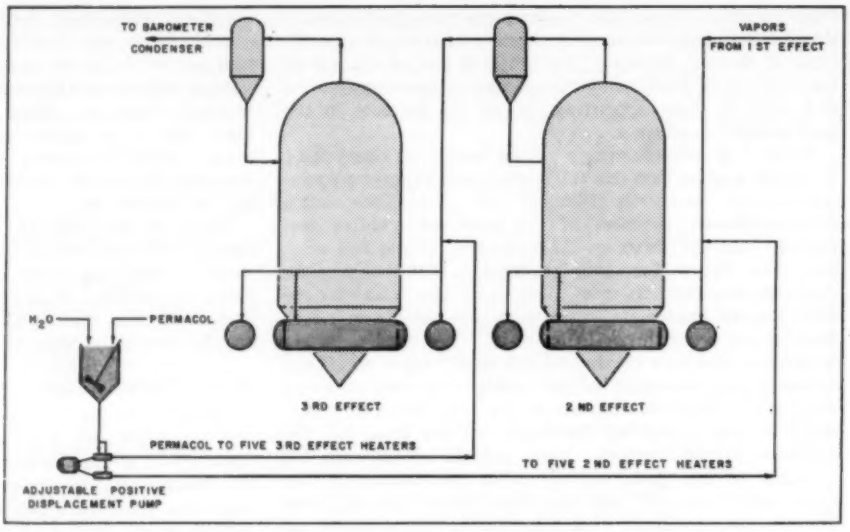


Fig. 5. Flow diagram of plant - scale experiments showing method of introducing promoter.

coated with a thin layer of lead. Six years is about the average life of these tubes, although, for maximum production, two years is closer to the optimum retubing frequency.

Preliminary full-scale tests were made in a single, third-effect heater equipped with sight glasses and an individual condensate measuring tank. Thermocouples were installed to measure the brine inlet and outlet temperatures, while the steam temperature was obtained indirectly by a vacuum gauge. Permacol was used in this and subsequent tests as the filming agent, and was injected as a 14% emulsion directly into the vapour line. The feed rate varied from 5 to 15 ppm (pure Permacol to steam). The heater contained 312 of the standard 2½ in. × 18 ft lead-sprayed, 14-BWG Admiralty tubes. Their age was four years, with the exception of four new tubes placed just above and below the steam baffle plate and clearly visible from the sight glasses.

Typical data obtained from the four days of intermittent operation are given in Fig. 6. These data indicate, as did all of the other data on this run, that the Permacol actually cut down the heat-transfer rate. Visual inspection showed that the performance of the new tubes was fairly satisfactory. The new tubes underneath the steam baffle exhibited good dropwise condensation. The new tubes above the baffle were heavily showered with condensate which ran off in rivulets, but even in the exposed areas there was no evidence of dropwise condensation. It appeared that the film of amine was too thick. None of the old tubes exhibited dropwise condensation at any time during the tests.

A probable explanation for the unexpectedly poor results is that the ocadecylamine film added its resistance to the flow of heat without aiding the dropwise condensation. However, owing to the intermittent nature of the tests, and their short duration, we felt that the results were not conclusive.

Tests were then made with all of the second- and third-effect heaters of the No. 3 unit, as shown in Fig. 5. No special measurements were taken around the heaters, for it was felt that the normal plant evaporator records should be sufficient to evaluate the results. Such evaluation would not be highly precise, owing to the multiplicity of variables that can affect the plant operation, but changes of from 2 to 5% of the heat-transfer rate should be observable. The reliance upon these data thus considerably simplified the test. The method of addition was to pump an emulsion of Permacol directly into the main vapour header, starting at the rate of 5 ppm for one month, raising this to 10 ppm for a second month, and then operating for 12 months at 15 ppm. The reason for this cautious start-up was to prevent a possible heavy sloughing off of scale from the tubes or condensate lines, which might plug the piping, and to observe whether any unusual effects took place in the system. Actually, no scale removal was noticed, and no difficulties were encountered. At the end of the first month, one of the third-effect heaters was retubed, thus providing clean tubes to be checked at the end of the test.

The results of the test were both surprising and discouraging. A statistical analysis of the year's operation was made, comparing it with the preceding year. The increased age of the tubes (average = 27 months), the changes in the pumps' capacities and other variables were taken into acount. There was only a fraction of a per cent difference in the two years' operation. In other words, the use of Permacol made no difference whatsoever in the evaporator's performance. To help explain these results, representative tubes were removed from three of the heaters, including the one retubed at the start of the test.

TABLE 2—Typical Vent Gas and Condensate Analyses

Analysis of Non-condensable Fraction, %				*Non-condensables in Total Vent Gas.*
H_2S	CO_2	O_2	N_2 (*by diff.*)	4.5
12.4	19.4	12.9	55.3	

Condensate	*Per Cent*	
	2nd Effect	*3rd Effect*
Ammonia, as N, ppm ...	12*	35*
Carbon dioxide as CO_2, ppm	13*	0*
Total hardness as $CaCO_3$, ppm	3	1
Phenolphthalein alkalinity as $CaCO_3$, ppm	0	37
Methyl orange alkalinity as $CaCO_3$, ppm	54	140
Sulphate as SO^{-}_4, ppm ...	7	36
Chloride as Cl^{-}, ppm ...	13	20
Silica as SiO_2, ppm	0.07*	0.09*
*p*H	7.5	9.2
Specific conductance, micromhos	112	270
Specific conductance, micromhos (corrected)	6.7*	143
H_2S	10.0*	11.2*

* Indicates only one analysis. Other numbers are based upon ten samples taken throughout one year.

These tubes were tested in the laboratory single-tube heater under a series of standard test conditions. No further Permacol was added to the steam.

As shown in Fig. 7, all of the tubes but the oldest ones exhibited dropwise condensation to a complete or partial degree. Fig. 8 is a cross plot of these data, comparing it with average expected coefficients when Permacol was not used. It is seen that a large heat-transfer coefficient improvement was obtained for the newest tubes, and that the improvement decreased as the tubes became older. Probably owing to the Permacol's partial corrosion protection of the tubes, even the oldest tubes, where no dropwise condensation occurred, showed some improvement. From this single-tube data, the average improvement in capacity should have been 21% for the unit's 27-month-old tubes. (This value would be smaller in the plant, taking into account that actual plant coefficients are reduced because of a salt scale inside the tubes, and would call for a plant improvement of from 10 to 15%.) Even if the one

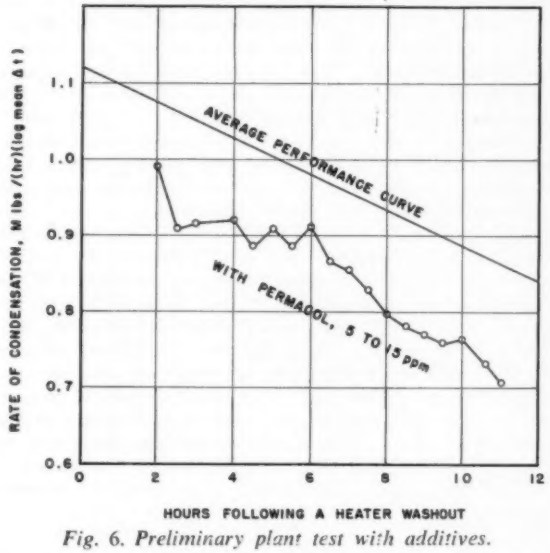

RATE OF CONDENSATION, M lbs /(hr)(log mean Δt)
AVERAGE PERFORMANCE CURVE
WITH PERMACOL, 5 TO 15 ppm
HOURS FOLLOWING A HEATER WASHOUT

Fig. 6. Preliminary plant test with additives.

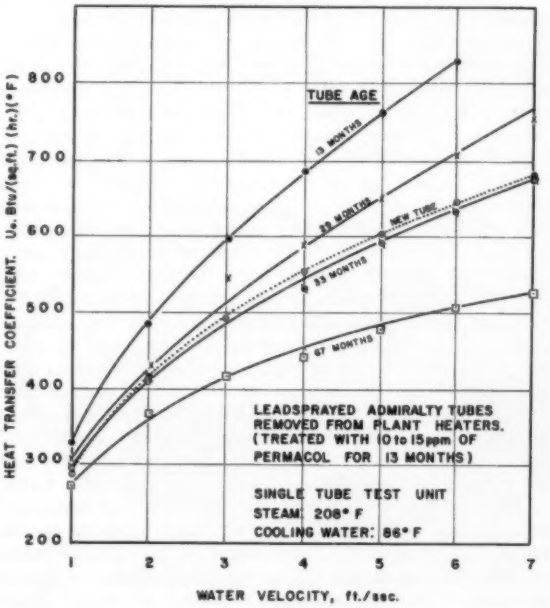


Fig. 7. Influence of promoter.

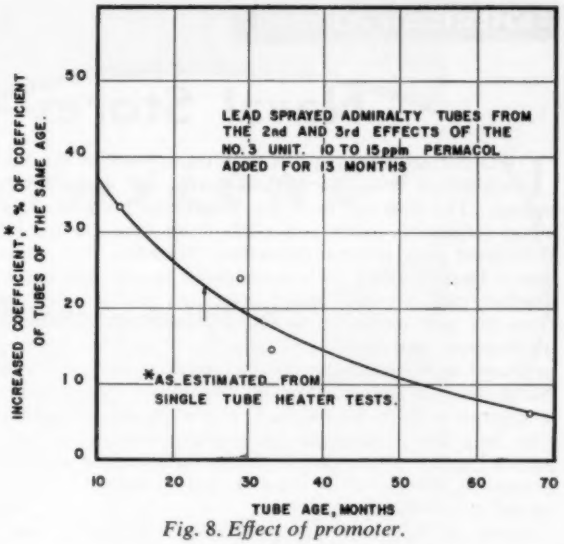

INCREASED COEFFICIENT*, % OF COEFFICIENT OF TUBES OF THE SAME AGE.
LEAD SPRAYED ADMIRALTY TUBES FROM THE 2nd AND 3rd EFFECTS OF THE NO. 3 UNIT. 10 TO 15ppm PERMACOL ADDED FOR 13 MONTHS
*AS ESTIMATED FROM SINGLE TUBE HEATER TESTS.
TUBE AGE, MONTHS

Fig. 8. Effect of promoter.

clean-tubed heater (at the start of the test) was the only one where dropwise condensation was effective, a 1 or 2% improvement should have been noticed, based upon the results of the tubes removed from the unit.

These data present a difficult problem in explaining the lack of effectiveness of the filming agent. Previous investigators have stressed the importance of "clean steam" and clean tubes. These are certainly factors that contribute at least to the magnitude of the steam-film coefficient, but we had demonstrated that dirty tubes could be made to give good dropwise condensation. We also showed that, even with our "dirty steam", the Permacol was coating the tubes and coating them to the extent that they at least exhibited dropwise condensation in the single-tube heater.

These may not be the direct reasons for the lack of positive results. Rather, it is thought that the single-heater, preliminary plant test, where sight glasses were available, indicated the more important cause. This was that the showering of condensate from a tube to the tubes below was sufficient to inundate effectively the lower tubes, and thus cancel the action of dropwise condensation. If the showering of condensate was so great that the fraction of uncovered tube area could not be large, then the mechanism of dropwise condensation would be counteracted. One reference[2] indicated that the steam-film coefficient, with dropwise condensation, on a 2-ft vertical tube decreased by almost one-fourth from the top of the tube to the bottom fifth. Neither this evidence nor the visual evidence through the sight glasses on the heater proves the point, but it does appear to be the most logical explanation to fit our available facts. If inundation is the explanation, it is likely that both "dirty steam" and dirty tubes accentuate the effect, so that one must not necessarily imply that other similar industrial applications cannot be effective. It will be interesting to see, however, how some of the other investigations under way at the present time[10] check these results.

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AMERICAN LETTER

Naval Stores—Old and New

TWO distinct developments have taken place in the old-established naval stores field during the last quarter-century. The first has been the large-scale production of wood turpentine, rosin and pitch from pine stumps by distillation and solvent extraction. Materials from this source have replaced, to a considerable degree, the sweet-smelling gum turpentines and associated products derived from the gum tapped from living pine trees. The second development has been the phenomenal rise of naval stores produced as by-products from Kraft pulp mills, both in North America and Scandinavia. Evidence of these changes is apparent even to distant, do-it-yourself home decorators, who may feel a nostalgia for pleasant-smelling, pre-war gum turpentines, with their excellent thinning and glossing properties, compared to some of the ranker turpentines on the market today.

Oddly enough, the U.S. production figures for rosin and turpentines have shown only about a 10% increase during the last 30 years, current annual rates being of the order of ¼ million tons of rosins and about 30 million gallons of turpentines. The large, overall, increased demand for resins, solvents and thinners has been met by synthetic products, petroleum and aromatic derivatives. A major limiting factor has been, of course, the availability of raw pine, which is closely associated with the paper pulp industry. Indeed, at one time, it was feared that the rapid harvesting and close-cropping of pine forests might seriously curtail the ultimate production of future naval stores. However, part of the reason for the decline of gum products is due to the unattractive labour conditions and rising operating costs for this type of field crop. As regards wood rosins and turpentines, despite predictions of a dwindling source of supply, due to smaller stumps occasioned by cutting younger trees, wood naval stores have actually risen in volume during the last decade. At present, about 25% of naval stores in America is derived from gum sources, some 55 to 60% from wood and about 15 to 20% from Kraft mills. Each of these three suppliers hopes to maintain or improve his share of the market by increased research in the laboratory and field, but the odds favour the sulphate mill operator, in view of versatile end-products such as tall oil.

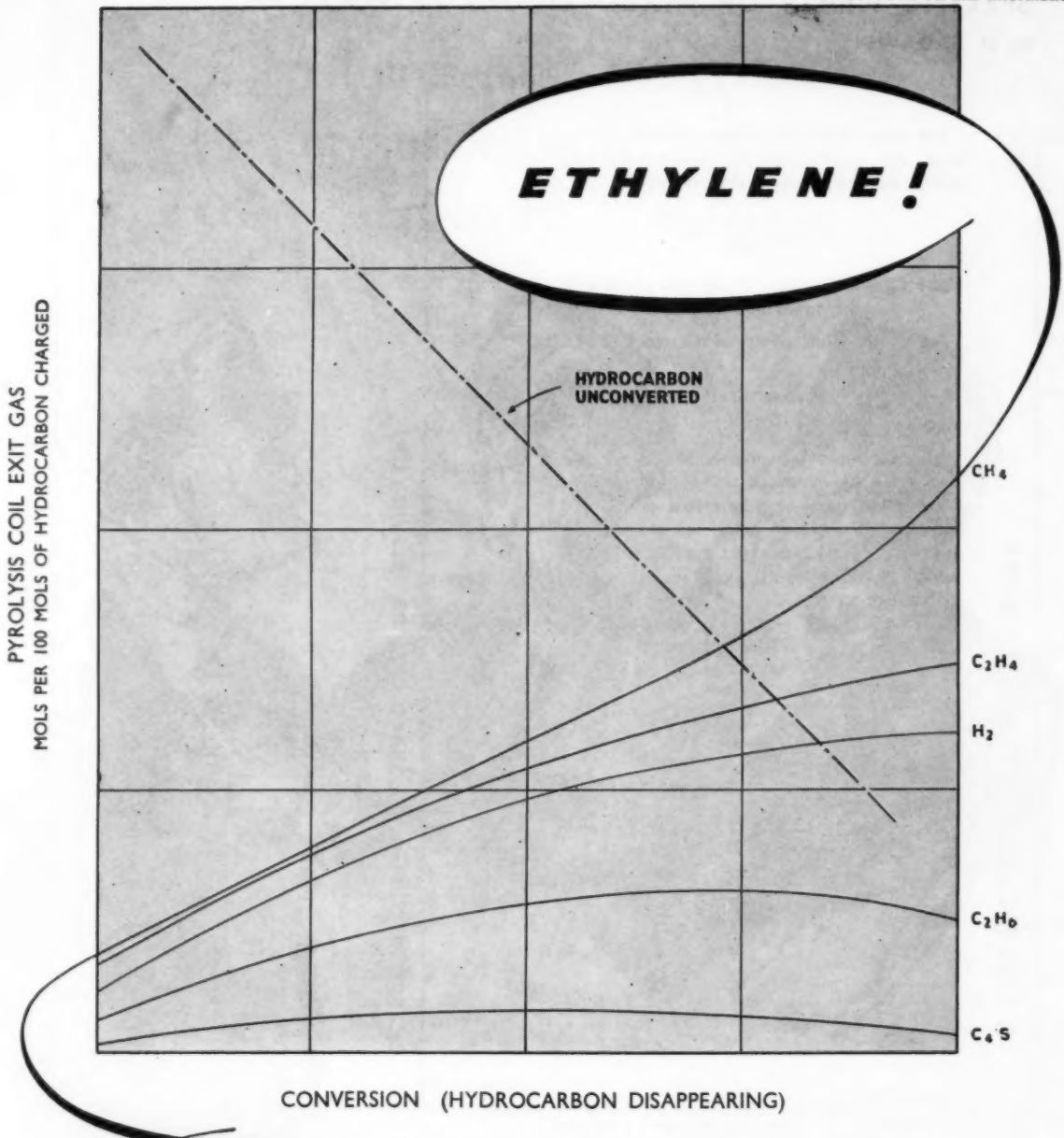
The production of sulphate, or Kraft pulp, involves virtually a simultaneous steam distillation and saponification as well. This results in a valuable yield of sulphate turpentine as a by-product (used for the production of pinene, etc.), in addition to alkaline soaps of rosin and fatty acids. Last year it was reported that more than half of the total turpentine produced was from this source, whereas a decade ago the proportion was about 20%. By far the most spectacular by-product, however, is tall oil.

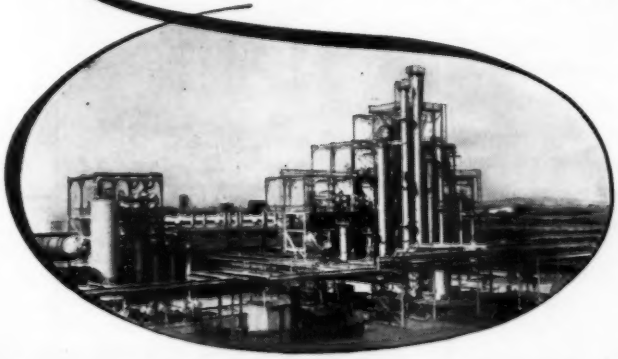
Tall Oil

The American Society for Testing Materials states that "tall oil is the natural mixture of rosin acids related to abietic acid, and of fatty acids related to oleic acid, together with non-acidic bodies, which is the product of the acidification of the skimmings from the black liquor of the paper pulp industry". This simple name (adopted from the Swedish word for "pine") and the comprehensive description are intended to include and render obsolete such ambiguous titles as lignin liquor, resin oil, Swedish resin, sulphate pitch, Swedish rosin oil and tallol. As the description implies, in making sulphate pulp, all fats, rosin acids, etc., in the wood are converted into soaps, which are washed out of the pulp and collect in the waste black liquor. On evaporation, the soaps separate as a brown curd known as skimmings, containing about 50% of solids. These soaps are collected and mixed with sulphuric acid to yield crude or "whole" tall oil. Like sulphate pulp, the output growth has been phenomenal; whereas the 1940 output was only some 13,000 tons, this had reached 300,000 tons by 1956 and is expected to achieve 500,000 tons or a billion (U.S.) pounds by the end of 1958, if the current recession ends.

Although considerable quantities of the unrefined oil are used directly, in the production of such items as floor coverings, core oils, soaps and flotation agents, it is said that some 60 to 70% of the total may soon be refined before use, so as to take advantage of the specific properties of the various refined products. In general, refined tall oil contains less than 80% of fatty acids—if this figure is greater, the product is termed "tall oil fatty acids". Two major refining processes are used, the solvent or acid process, and distillation. The solvent process utilises acid washing in conjunction with solvent distillation and until 1955 about two-thirds of all refined tall oil sold was reported to be produced by this method. The distillation (fractionation) processes are mostly based on injected steam, plus reduced pressures to prevent breakdown of the rosin and fatty acids. Yields may be 30 to 80%, depending on the crude oil used and the products desired, compared to 80 to 90% yields for the acid-solvent process. Usually appreciable fractionation occurs, so that the distilled oil has a higher fatty acids content than the original oil. For instance, a fatty acid fraction containing 1 to 5% rosin and a rosin fraction containing 75% rosin may be obtained; even solid tall oil rosin can be produced if desired, with specific properties according to customer requirements. Recent plants are designed to produce tall oil fatty acids and rosin, instead of refined tall oil, since new uses for the many fatty acid and rosin derivatives are constantly being found. At present, about 10 large fractionating plants are on stream or under construction in U.S.A., designed for the continuous refining of tall oil. Some of these are operated by major chemical producers such as Armour, Hercules and American Cyanamid, while others are subsidiary plants of the pulp and paper companies, such as West Virginia and the Union Bag-Camp Co.

As with crude tall oil, the many uses of both the solvent refined and the distilled oils are based on two main factors, the surfactant and the drying properties possessed by these products. According to the U.S. Tall Oil Association, about 40% of production goes to fulfil surfactant needs, while over 50% is used where drying oils are necessitated. The range of current and potential uses is astonishing, particularly for a relatively new material. This may also be partly due to the fact that, in numerous cases, users of solid rosin can incorporate a liquid tall oil with much greater ease, and often superior results. The ability to form esters with polyalcohols such as glycerol, penta-erythritol and sorbitol, for instance, has led to important end-uses, especially with the inclusion of dibasic acids such as phthalic and maleic, to give alkyd resins. Compounds of tall oil and derivatives with styrene and vinyl toluene also have valuable specific properties, while epoxy resins based on tall oil have immediately been put to use by enterprising chemical engineers, on account of their excellent resistance to attack, under many adverse conditions.





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SPECIFIC HEATS OF MIXED LIQUID PETROLEUMS

by D. S. DAVIS*

For mixed liquid petroleums, FORTSCH[2] correlated the specific gravity, temperature and specific heat by means of the expression

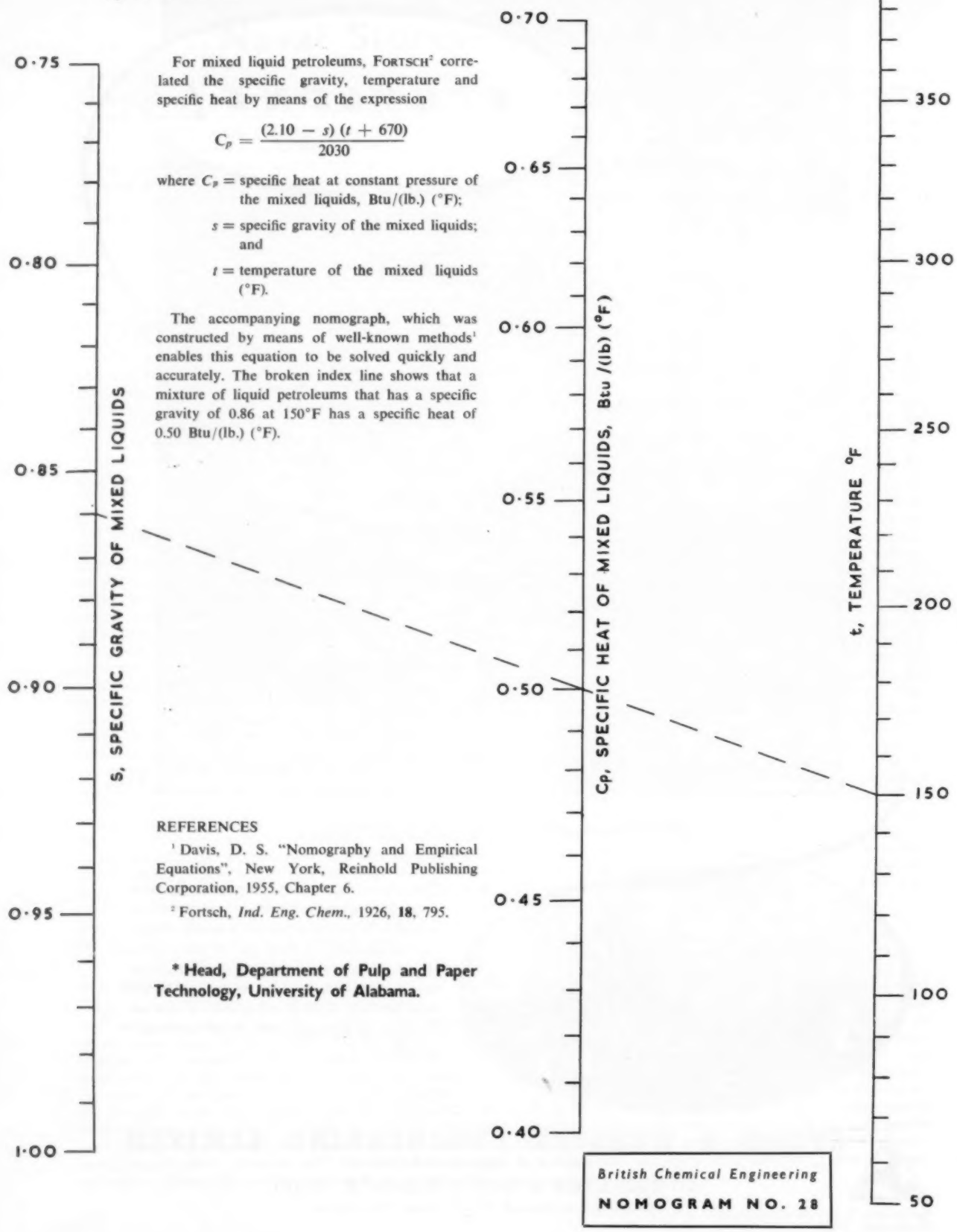
$$C_p = \frac{(2.10 - s)\,(t + 670)}{2030}$$

where C_p = specific heat at constant pressure of the mixed liquids, Btu/(lb.) (°F);

s = specific gravity of the mixed liquids; and

t = temperature of the mixed liquids (°F).

The accompanying nomograph, which was constructed by means of well-known methods[1] enables this equation to be solved quickly and accurately. The broken index line shows that a mixture of liquid petroleums that has a specific gravity of 0.86 at 150°F has a specific heat of 0.50 Btu/(lb.) (°F).



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* Head, Department of Pulp and Paper Technology, University of Alabama.

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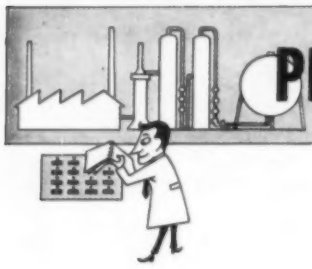
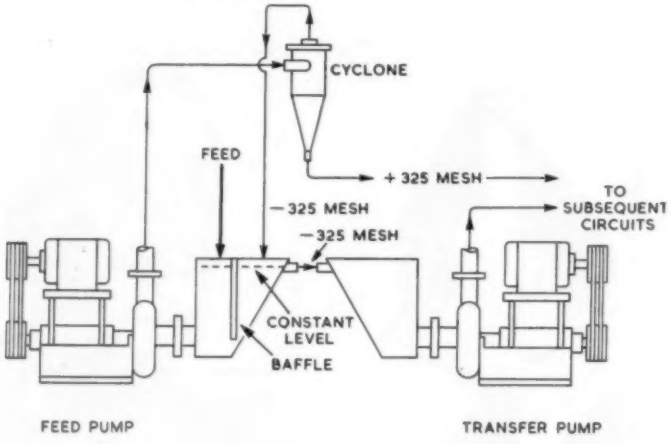


PROCESS ENGINEER'S NOTEBOOK

Maintaining a Constant Pressure to Wet Cyclones



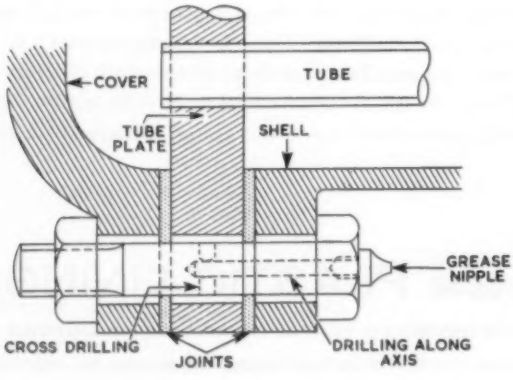
SUCCESSFUL CLASSIFICATION depending upon the use of cyclones requires a constant volumetric feed to the cyclone so that it can operate at a constant pressure. The wet cyclone is used extensively in the uranium field for making 325-mesh separations. In most plants employing the wet cyclone, the feed is provided by means of a centrifugal pump. There is a difficulty, however, that fluctuating level in the pump sump may lead to a change of pressure at the cyclone. A method of avoiding this difficulty is shown in the accompanying diagram. A constant level is maintained in the sump through taking the −325-mesh discharge back into the sump together with the feed. An overflow from this sump to the feed sump of the transfer pump helps to maintain a constant level in the primary feed vessel and ensures transfer of the fine slurry to the later stages of the process. If the amount of feed is reduced, the previously classified −325-mesh slurry provides the necessary make-up feed to the pump and ensures a constant level in the sump and therefore a constant volume feed to the cyclone. Sometimes gravity flow alone from the feed tank may be used instead of the transfer pump.

Courtesy of Denver Equipment Co.

Curing Joint Leaks without Dismantling

THERE ARE SOMETIMES occasions when leaks develop at large flanges on distillation columns or condensers. To carry out an orthodox repair by dismantling and rejointing could mean a very long and costly job, and on some types of condensers and coolers would involve the removal and replacement of the complete set of tubes. With the following idea, dismantling can be avoided and the author has found it to be effective on many occasions.

Briefly, the idea consists of the removal of several flange bolts adjacent to the leak and the replacement of these by special hollow bolts through which jointing compound may be forced. The accompanying sketch gives details of the special bolts, which, it will be seen, are drilled along their axis. The bolts are tapped at the head for a grease nipple, and cross-drilled at the point where the jointing compound should emerge. The grease gun is filled with "Permac" or any other thermal setting jointing compound, and then used to force the compound through the bolt. This should be done when the joint is hot and the special bolt should be left permanently in place as, since these bolts are very easy to make, there is little point in attempting to remove them, which might break the seal which has been made. While forcing the jointing in, it is an advantage to take off any pressure in the vessel being dealt with, and, if possible, allow an hour or so to let the jointing set. However, it is appreciated that this is not always possible, and the author has effected cures by this method when a distillation column has been in service and under pressure.

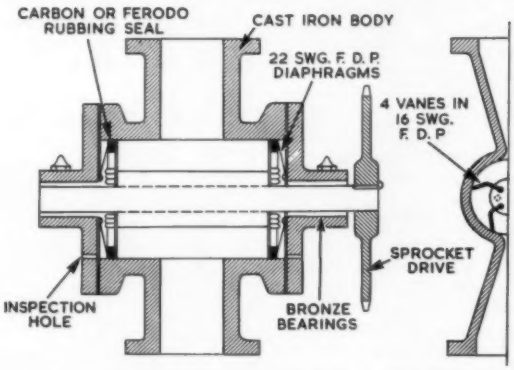


R. H. B. MATTHEWS

Removing Obstructions from Tubular Equipment

ALTHOUGH FOREIGN BODIES like tools do not often find their way into the interior surfaces of tubular equipment, the removal of such bodies when something of the kind does occur is sometimes quite a problem. Instances have been known to occur during maintenance operations on pipework. One particular case which came to our notice occurred when a valve in a vertical-pipeline section was being replaced, when a knife used for smearing jointing compound on the flange faces fell inside the pipe and became lodged in a 90-degree bend fitted some feet below the valve joint. A number of attempts were made to remove the article without success, using such methods as a length of water hose to try to move the knife. A successful method made use of compressed air and a rubber bung. The bung was attached to a length of fishing-line and was lowered down the tube; the open compressed-air connection was held just inside the tube. The air was then turned on and, fortunately, the pumping effect of the jet produced enough speed to the bung to loosen the knife and remove it from the bend. The knife and bung were recovered from a break in the pipework made upstream of the bend.

Modifications to Rotary Valve


CARBON OR FERODO RUBBING SEAL
CAST IRON BODY
22 SWG. F. D. P. DIAPHRAGMS
4 VANES IN 16 SWG. F. D. P
SPROCKET DRIVE
INSPECTION HOLE
BRONZE BEARINGS

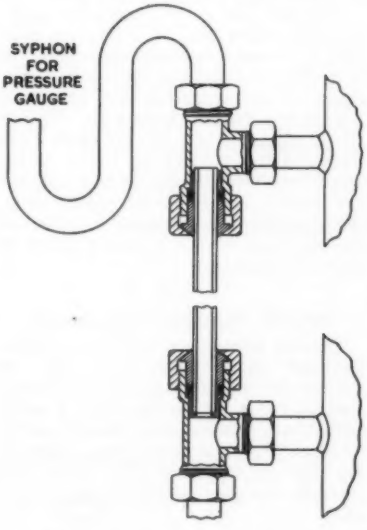
IN OUR AUGUST issue, page 450, the illustration referred to in F. Molyneux's contribution to "Process Engineer's Notebook" was inadvertently omitted. We reproduce the missing diagram above, which shows the modified internal structure of the star rotary valve.

Water Level Gauge from Tee Fittings

A WATER-LEVEL GAUGE was required on a small-diameter vessel, but in the interests of economy and appearance the usual heavy construction gauge complete with cocks was not considered to be ideal. Instead, a suitable water-level gauge was made by using two compression-type tee fittings (Ermeto). The advantages of this method are:

(1) Special water-level gauge bosses are not required on the vessel; two short pieces of ½-in. N.B. steel pipe are welded to the shell and the tees fastened to these.

(2) The third arm on the top tee may be used for a pressure gauge syphon and on the bottom tee a drain cock may be fitted, thus dispensing with separate bosses for pressure gauge and drain.



For use with ½-in N.B. tee a ⅜-in. o.d. glass tube was selected, since this would pass through the top fitting and allow easy assembly. Two small gland fittings were made in brass for each end of the glass tube and the assembly completed by two rubber gromets. Although it is permissible (according to the Factories Act) to operate an unguarded water-level gauge up to 40 psig, a piece of gauze may be wrapped around the tube and securely wired at each end to the top and bottom fittings. To facilitate welding the short pipes to the shell the tees may be assembled on to a length of ½-in. N.B. pipe and the short pipes into the tees which ensures accuracy of alignment.

Measurement of Flow of Jacket Liquid to Vessel

ON THE SMALL-SCALE PLANT for the preparation of chemicals involving exothermic reactions, the customary practice is to pass water through a jacket, assuming that a jacketed vessel is being used for the reaction. Depending upon the amount of heat liberated in a reaction, the amount of coolant may be unimportant or else critical, and in some instances a simple method of flow indication is necessary. One way of measuring flow through the jacket is to install a pressure gauge in the coolant feed pipe and another on the jacket. The difference in readings between the two will give a good indication of the rate of flow. It is not claimed that this method will give a high degree of precision, but it will be good enough to indicate the order of flow which is generally all that is required for this kind of process.

Contributions invited

THE EDITOR invites readers to submit, for possible publication in "Process Engineer's Notebook", notes on practical devices that have been elaborated on the job for improving the operation or increasing the safety of processes, or that have been extemporised in special circumstances. The contributions preferably should be of about 250-500 words, and be illustrated with a line diagram or sketch, or a photograph. A minimum of three guineas will be paid for each contribution used. They will be published anonymously or under the contributor's name, according to his wishes.

World of Chemicals

Nuclear Engineering Developments

Two exhibitions are to be held in Geneva during the second international conference on the peaceful uses of atomic energy, from September 1 to 13, organised by the United Nations. The U.N.'s Governments' Scientific Exhibition will cover four times the space of the equivalent exhibition at the first conference in 1955, and a temporary building of 7000 sq. m. is being erected to accommodate it. Twenty-one governments are taking part in the exhibition, in which a dominant theme will be the use of fusion processes for the production of useful energy. The United States will be the largest exhibitor, with over 3000 sq. m., followed by the U.S.S.R. (1000 sq. m.) and the United Kingdom (500 sq. m.).

In the commercial exhibition, arranged by the Swiss authorities, the United Kingdom exhibit (3600 sq. m. of the total 11,000 sq. m.) will be the largest, and nearly 80 United Kingdom companies will be showing there. The exhibits will include models of nuclear power stations and research reactors; equipment such as pumps, valves, and filters of conventional design but manufactured mostly to unusually close tolerances; fuel element cans, heat exchanger tubes, and wrought or fabricated products from special metals, and control instruments. Other exhibits on the British stand will include test plants for metal-to-steam heat-transfer problems and an advanced type of plant for the production of heavy water. The manufacture of isotopes will also be featured. The British exhibits are being co-ordinated by the Nuclear Energy Trades Association Conference, 32 Victoria Street, London, S.W.1.

The French atomic pile G2 was commissioned recently at the Marcoule Atomic Establishment near Avignon. It is of the Calder Hall type, using natural uranium with a graphite moderator and cooled by gas under pressure, and it is designed to produce electricity and plutonium. Construction commenced in 1955.

Finland's first experimental reactor was commissioned recently by the Voimayhdistys Ydin (an association of eighteen industrial undertakings). The uranium for it was bought from the United Kingdom, the neutron source from the Soviet Union, and the graphite reflector from the U.S.A.

Ethylene Oxide Installations

The first plant in the United States to use the Shell Development's process for the manufacture of ethylene oxide by the oxidation of ethylene with pure oxygen instead of air was commissioned by Wyandotte Chemicals, Geismar, U.S.A. The plant, which will cost $11 million, has been built by Lummus and has a yearly capacity of 60 million lb. About 80% of it will be converted to ethylene glycol. A similar plant is nearing completion at the Lake Charles installation of Calcasieu (a subsidiary of Petroleum Chemicals) and a plant of 50 million lb. (25,000 tons) annual capacity is well under way at the Shell Chemical Co.'s establishment at Partington, England.

Union Carbide Chemicals have decided to defer the construction of a plant at Putnam, West Virginia, for the manufacture of ethylene oxide, ethanol and other products. It had been planned for completion by 1960, and a delay of two or three years is now being contemplated. The output of ethylene oxide would have been 150 million lb. annually. Current business conditions, the company say, have slowed consumer demand for the chemicals.

Chinese Industrial Expansion

Among the industrial expansion being undertaken at present in China is the enlargement of the Peking chemical plant. By the end of the year it is hoped that it will be in a position to produce reagents, rubber anti-oxidants, catalysts, titanium, strontium, zirconium, tantalum, beryllium and molybdenum. The Yungli-Chiuta chemical works in Tientsin are also being expanded to provide for an annual output of 160,000 tons of ammonium chloride and of pure soda. A new gas-compressor has been installed in the Yungli chemical works in Nanking to provide a 20% increase in the production of liquid ammonia. Construction has also begun of a new chemical fertiliser plant in Kaifeng, Honan. By next year it is to produce 200,000 tons each of phosphate and nitrogenous fertiliser. Double superphosphate will be produced later. An 8000-ton nitrogenous fertiliser plant has begun production in Shanghai, and it will serve as the prototype of 36 plants to be built this year in various parts of China. Ion-exchange resin is to be mass-produced at the joint State-private Shanghai resins plant. Other new products turned out by this plant include heat- and cold-resistant silicate plastics.

German Companies' Progress

During 1957 the turnover of Farbwerke Hoechst A.G. and its associated companies rose by 18.9% (to DM 1,760 million, £150 million) compared with 11% for chemical industry as a whole in the Federal Republic. The export ratio rose to 32% compared with 30% in the previous year, and 74% of the total turnover went to countries which now form part of the European Common Market. The company states the view in its annual report that expansion in the German chemical industry is likely to slow down, as it has done in industry as a whole. Plastics, solvents, lacquer components, fibres and foils accounted for 35% of Hoechst's turnover, with the balance being distributed over dyestuffs, textile auxiliaries and organic intermediates (16%), pharmaceutical products (12%) and inorganic chemicals, fertilisers, plant protection agents and miscellaneous products (37%). Expenditure on research and development totalled some DM 88 million and represented again 5% of the total turnover.

Dr. U. Haberland, chairman of Farbenfabriken Bayer A.G., in his address to the annual meeting of the company recently, said that recent large investments had raised the company's productive capacity to the point where it could slacken the speed at which it has been extending its plant. During the next year DM 300 million would be spent on Bayer and Agfa as compared with DM 360 million in the previous year. During 1957 the company's turnover rose by 16%, as compared with 1956, to DM 1853 million.

Mexican Sugar Refining

The Mexican sugar refinery of El Potrero has just been granted a U.S. $3 million loan for repayment over ten years to enable it to be modernised and expanded. The shareholders of the El Carmen sugar refinery are to finance a 25-million pesos (£720,000) paper factory to be built at Corboda, Vera Cruz, to produce kraft paper.

Uses for Beryllium

For the test reactor under construction at Möl, Belgium, by the Centre d'Étude de l'Energie Nucleaire, beryllium metal to the value of $1.2 million has been ordered from the Brush Beryllium Co., Cleveland, U.S.A.

Mass production of a copper beryllium mixture is to be started in Japan by the Nippon Gaishi K.K. (The Japan Insulator Co.). The method of production is said to involve the use of beryllium oxide extracted from emerald, and the procedure was elaborated after three years of research with the assistance of a Y10 million (£9800) government subsidy.

Sea-water Distillation Plant

The first part of the sea-water distilling plant being installed on the island of Aruba, in the Caribbean Sea, by G. & J. Weir Ltd., Glasgow, has commenced operation and is adding more than half a million gallons of fresh water daily to the island's supplies. The complete plant will, it is thought, be the largest in the world. Work is also proceeding on large installations to provide fresh water from the sea in the adjoining island of Curaçao and in the British Colony of Nassau (Bahamas).

Organic Phosphates in Canada

Organic phosphates are to be manufactured on a commercial scale in Canada for the first time by the Electric Reduction Co., of Canada, Ltd., a member of the Albright & Wilson group. They will be produced at the company's Buckingham (Quebec) plant which was recently expanded considerably.

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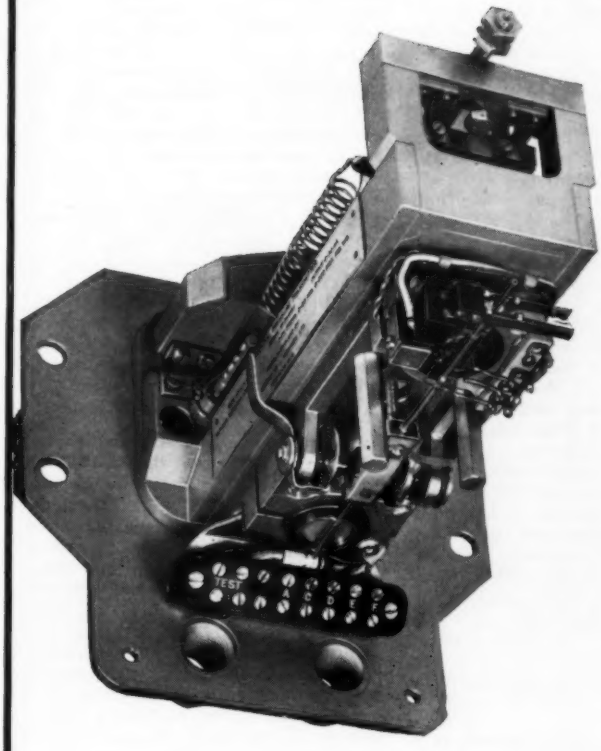

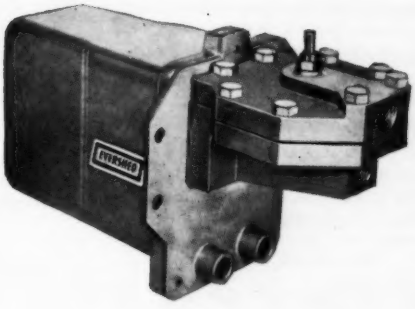

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Book Reviews

Plant Design and Economics for Chemical Engineers
by Max S. Peters
McGraw-Hill, London, 1958, 495 pp., 85s. 6d.

THE subject of cost estimating for chemical engineers offers little, if any, scope for great originality. There is already an extensive literature characterised by much reiteration and, to take a case in point, this is the fourth book on this subject from the same publishers. Under the circumstances, one is justified in fearing that this will be just another "scissors and paste" production. On reading the book more closely, this first reaction gives way to one of warmth towards the author. As one suspected, most of the material has appeared elsewhere, but here it has been gathered together in a most systematic manner to make by far the best contribution, to date, on this subject. The coverage is comprehensive, unfailingly systematic and well documented with references to the original publications. It is also surprising that an author with such a lively interest in his subject cannot carry it a bit further. The whole book is written around the well-known procedure of basing the capital cost on the cost of delivered equipment. In this method only the latter figure is known with any accuracy. It must also be possible to derive equally simple procedures for determining at least some part of the balance (roughly 80%) of the fixed capital cost.

At no stage in the development of a process or the construction of a plant is it possible to completely eliminate value judgments on the part of the estimator. For this reason, a welcome feature of this book is the frequent allusions to order of cost and the numerous tabulations which relate various cost elements to some easily determined parameter. Thus we have tables of unit investments and turn-over ratios for numerous processes, and many other useful tabulations referring to piping, insulation, installation, building and other costs.

The outstanding sections of the book are those dealing with alternative investments and replacements and with optimum design. A sound, theoretical basis is laid down for the economic comparison of alternatives and for the economic evaluation of replacements. The methods outlined are direct and readily understood by engineers who tend to be repelled by the more involved procedures of cost accounting. Although, as the author is careful to point out, theory in matters of economics often must yield to other practical considerations, a theoretical attack is the best way of getting to the heart of a problem of this kind. For the same reasons, the author's preoccupation with and extensive treatment of optimum design is valuable. This subject is touched on in the introduction and is subsequently given full theoretical treatment in a separate chapter. In later chapters concerned with particular unit operations, the principles of optimum design are applied to specific unit operations.

The treatment of unit-operations equipment occupies about half the book. The treatment in each case follows the same pattern. The theoretical principles on which design may be based are outlined. The treatment is a reminder of basic theory rather than a complete exposition. However, sufficient is given to guide any initiate in chemical engineering in the task of sizing the equipment well enough for estimating purposes. This is followed by a discussion, both theoretical and practical, of the factors to be considered in selecting the appropriate form of equipment. The next step is to give tables or graphs setting out equipment costs in terms of some criterion of size. Thus, costs of exchangers are plotted against area of heating surface. There then follows a section on optimising of the design. The mathematical treatment of optimum design procedures is rather more advanced than the treatment of design itself. This is a possible weakness of the book, but design procedures have been dealt with fully in a number of other texts. From the British reader's viewpoint, of course, there is this regret—dollar costs are not a reliable guide to costs in this country.

Both the novice and the initiate have received due consideration from the author. All the major points as they are made are brought home with worked illustrations, and a good selection of practice examples is provided.

J. E. CRAN

Pressure Measurement in Vacuum Systems
by J. H. Leck
Chapman & Hall, London, for the Institute of Physics, 1957, 144 pp., 30s.

WHILST DUSHMAN's work, "Scientific Foundations of Vacuum Techniques", has become the "bible" of the vacuum engineer, there is undoubtedly a need for a smaller, handier book on the more practical side of vacuum measurement. MR. LECK's book, published in the "Physics in Industry" series, is in the same category as "Modern Mass Spectrometry" by BARNARD, and promises to fulfil this need. It is well written by an author who has had practical experience in this field; the printing is attractive, and the illustrations, mainly line blocks, are plentiful and clear; and there are few typographical errors.

The book gives a simple mathematical analysis of the physical principles underlying the types of gauge which can be used in vacuum work both in the laboratory and industry. The results of other workers are surveyed, freely described and quoted, and many references are cited for those who wish to pursue individual papers in greater detail.

The book is divided into six sections, four large and two much smaller. The first four sections each deal with a particular class of gauge: the experienced vacuum engineer would loosely call these the MCLEOD, PIRANI, Ionisation and KNUDSEN sections. Other types of gauge are, of course, described, but these are the types which are of main interest to everyone and are in widespread use. The sizes of the sections give some indication of their relative importance; thus the "PIRANI" and "Ionisation" sections together occupy almost half of the book. In these four sections the problems associated with the various gauges are discussed in some detail. The fifth section, specially devoted to techniques used in the study of surface reactions, describes ways of estimating pressures below those normally encountered in most laboratories, while the sixth section gives a brief summary of some methods of calibrating gauges.

It is obviously impossible to give a complete survey of all possible methods of pressure measurement in what is essentially a handbook, but some mention might have been made of the "omegatron" type of ion gauge as used by ALPERT, since this is potentially a powerful tool in high-vacuum work. Nevertheless, this book has much to recommend it and will undoubtedly find a well-thumbed place in most laboratories where vacuum work is done.

J. BISHOP

Communications and Electronics Buyers' Guide, Who's Who and Reference Book
Heywood & Co. Ltd., London, 1958, 105s.

AS chemical engineers are among the major users of electronic measuring control and data processing equipment, they will be interested in this new book, published on June 30, which contains over 32,000 verified references, gives details of some 1400 firms concerned with the development and manufacture of around 2750 different types of product and, apart from the comprehensive Buyers' Guide section, contains a 74-page section of technical product surveys which should be of particular interest to chemical and plant engineers. We feel that this pioneer book will go a long way to making more widely known the products of the complex electronic and instrument industries to the equally complex industry of chemical engineering.

Scaling-up of Chemical Plant and Processes: Proceedings of a Joint Symposium
Institution of Chemical Engineers, 1958, 136 pp., 60s (To members of bodies sponsoring the Conference, 40s.)

IN MAY 1957 a symposium on scaling-up of chemical plant and processes was held in London. It was sponsored by Het Koninklijk Instituut Van Ingenieurs (Chemical Engineering Group), De Koninklijke Nederlandse Chemische Vereniging (Section for Chemical Technology), the Society of Chemical Industry (Chemical Engineering Group) and the Institution of Chemical Engineers. The 13 papers and the report of the discussion have now been published by the Institution of Chemical Engineers. Apart from a general introduction, the papers deal with a series of specific design problems, such as those of reactors, cyclones, air separation plant, furnaces and continuous filtration.

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Book Reviews continued

Mechanical Engineering Thermodynamics

by David A. Mooney

Longmans, Green & Co., London, 1957, 540 pp., 45s.

THE text of this work on mechanical engineering thermodynamics consists of 25 chapters and comprises 498 pages, together with an appendix of definitions of symbols, and various tables and charts of property values of a number of fluids. The presentation follows the almost generally accepted pattern of dealing first with the fundamental concepts of work, temperature and heat, and properties of systems. In Chapters 5 to 8 the reader is introduced to the First and Second Laws of Thermodynamics, interspersed with a study of flow processes, using the control surface technique, and basic applications, which cover entropy, reversibility and the availability of energy. The next four chapters are concerned with the properties of vapours and gases and gas mixtures, while Chapter 13 is devoted to process calculations for stationary systems. This is followed by an examination of both ideal and actual gas and vapour cycles, and a chapter on fluid flow through nozzles and orifices.

Chapters 18 to 21 cover respectively turbines, reciprocating expanders and compressors, reciprocating steam plant and gas compression. Combustion processes and internal combustion power plants are next treated, and there is then a section on refrigeration. The final chapter is devoted to air-water vapour mixtures. Most chapters carry a suitable selection of problems; in the writer's opinion, it is a pity that the usual American practice is followed of omitting to give answers, either after each problem or at the back of the book.

One unusual feature of the book which is likely to make it attractive is that both gas-table and gas-law solutions are given to problems worked in the text. At the same time the book suffers from the order of presentation, so far as gases are concerned. Air-water vapour mixtures, which are left till the last chapter, might well have followed the properties of gaseous mixtures in Chapter 12. It also seems odd that gas compression (Chapter 21) should be separated from reciprocating compressors (Chapter 19) by a chapter on the steam engine. A significant omission from the book is a section on heat transfer, though the author has apparently written a second and abridged text in which this subject is included. Another topic which nowadays usually finds a place in thermodynamics text-books is the work leading up to Maxwell's thermodynamic relations. It will be clear from the foregoing that there is little in this book of special interest to chemical engineers.

A statement in the preface which may arouse controversy is that "the steady flow energy equation is developed as a special restricted application of the First Law; the misleading implication that it is in any sense a more general equation than the First Law is avoided." This seems at variance with what is written on page 67, that "Chapter 5 (dealing exclusively with the First Law) was devoted to the *special* case of a pure substance in the absence of *motion* and *gravity*. Since many practical engineering operations involve flow of fluids, it becomes desirable to develop the First Law for convenient application to flow processes." In the writer's view this can only imply development from the particular to the general.

B. W. MARTIN

Catalysis in Practice

Edited by C. H. Collier

Chapman & Hall, London, 1957, 153 pp., 31s.6d.

THIS is a collection of seven papers presented in April, 1957, at a one-day meeting sponsored jointly by the Philadelphia-Wilmington Section of the American Institute of Chemical Engineers and the School of Chemical Engineering of the University of Pennsylvania. The scope of the papers was limited to existing technology in the chemical and petroleum industries and the aim was to provide younger chemical engineers with information of practical use. The papers are presented as chapters. Chapter 1 discusses the selection of the catalyst mainly for processes involving solid-catalysed, vapour-phase reactions. Chapter 2 deals with the preparation of catalysts on a commercial scale. Chapters 3 and 4 present practical engineering aspects of fixed- and moving-bed systems respectively with evaluations of the advantages and disadvantages of each. The economics of catalyst use and the cost aspects of the various stages in a catalytic process are discussed in Chapters 5 and 6. Chapter 7 looks briefly at future trends in catalysis in the light of current developments in the polymer, petroleum refining and nuclear fields.

The chapters of this small book vary greatly in their content and quality. In the best of them there is much valuable practical information particularly on the choice and preparation of catalysts and on fixed- and moving-bed catalytic systems. Fluidised systems are commented on here and there, but are not considered in any detail, which is somewhat surprising since commercial catalytic cracking is freely used by different authors to illustrate the argument. Economic considerations of catalytic processes are rightly emphasised throughout and are not confined to the chapters specifically covering this aspect. One feels that when the papers comprising the chapters of this book were presented, useful discussion must have been provoked; if so, it is not given. Theory of catalysis did not come within the scope of the papers, but the industrial research worker, whose bible may be Emmett's "Catalysis", could read this book with profit as well as the chemical engineer for whom it is primarily intended.

A. MCLEAN

Modern Mathematics for the Engineer

Edited by Edwin F. Beckenbach

McGraw-Hill, London, 1955, 154 pp. 58s.

THIS book consists of 19 chapters, 18 of which are written by different authors, each of whom is a specialist in his particular subject. This means that the book exhibits a rather wide diversity of styles from the rather elementary exposition to, in at least one case, the obscure. Because of this, it is difficult to assess the book as a whole, but an idea of the purpose behind its publication may be gained from the preface. Here it is stated that the book is the outcome of a series of lectures intended "to generate in the minds of engineers and applied scientists engaged in research, design and administration an awareness of the recent rapid advancement in applied scientific thought, an advancement resulting largely from the demands of modern engineering programming and design made possible in part by recent advances in basic mathematics and statistics and by the development of analogue devices and digital computing machines of extremely high capacity and speed". This is slightly misleading, as much in the book has little to do with computers directly, and a much wider field is covered than one would imagine from the quotation given above.

The book is, in fact, an introduction to certain selected mathematical topics which may be of use to engineers. Each chapter deals with a different subject, and these subjects are grouped to form three sections. Part 1 is called "Mathematical Models", Part 2, "Probabilistic Problems", and Part 3 deals with "Computational Considerations". The bias is towards mechanical and electrical engineering. On the other hand, some of the basic theory is of general application and will interest chemical engineers, whilst some of the other topics are of potential use in this field. Of the 19 authors, 16 are mathematicians and three are engineers. Because the mathematical approach is, on the whole, of the formal academic nature usual in American text-books dealing with advanced topics, the average engineer may find parts of the text difficult to appreciate because he will not have the right type of mathematical background, as engineering mathematics is not taught so formally in this country.

Although this book can be strongly recommended as an introduction to certain advanced mathematical topics, it must be emphasised that it is a book written by mathematicians with few concessions to those whose occupation is with other fields of knowledge.

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This year Mr. J. Arthur Reavell, M.I.Mech.E., M.I.Chem.E., F.Inst.F., F.I.M., celebrates his fiftieth year as Chairman of the Company he founded, The Kestner Evaporator and Engineering Company Limited. Although now 86, he is found in his office on most days of the week and annually visits his overseas branches.

The company came into being because Mr. Reavell's great friend, the famous French physicist, Paul Kestner, wished him to take over the Empire rights of the evaporator and other Kestner patents. Since then, he has added a long string of his own patents. Today, there is scarcely an industry in which Kestner plant is not used. For Kestner have always been the pioneers in design, adapting new materials to new processes, and from still newer processes evolving still newer materials.

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As Mr. Reavell says, 'I have lived a full life and intend to go on doing so'. And it is the sincerest wish of his colleagues and employees that he may long be spared to inspire them to maintain and enlarge the high reputation in chemical engineering that has been held by Kestner for half a century.

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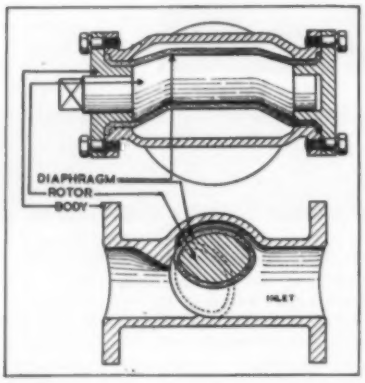
PLANT EQUIPMENT NEWS

MOST of the valves and pumps described below were shown to the public for the first time at the 1958 Chemical and Petroleum Engineering Exhibition, London.

Valves

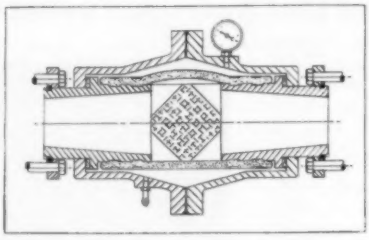
Diaphragm Valves

Patent protection has been sought in the principal countries of the world for the new Merrill diaphragm valve, whose diaphragm is a plain flexible tube with no mechanical attachments. It isolates the rotor and the end caps from contact with the line fluid. The pressure exerted on its wall when the valve is closed is predetermined by the radii machined on the rotor and on the seating and cannot be exceeded. The elliptical rotor rolls the diaphragm on to the body seating with sufficient "interference" to comfortably



hold the required line pressure. The diaphragm is supplied in rubber, Neoprene, butyl, plasticised PVC, chlorosulphonated polyethylene and other materials. The valve body is cylindrical across the axis of the pipeline. It has a raised machined seating and smooth internal contours well adapted for lining with rubber, glass or plastics, and it can be supplied in cast iron, stainless steel, bronze, aluminium, etc. Turning the rotor (with a wrench) moves the wall of the flexible tube to a position shown on the indicator scale on the end cap. No attention is required, the makers say, until the diaphragm ultimately becomes worn or damaged. A replacement is then easy to fit.

Merrills have also introduced a tube-diaphragm pressure-relief valve. By pumping air through a Schrader valve, a pressure, indicated on a gauge, is built up in its air chamber. When the fluid pressure exceeds the air pressure a flexible tube is pushed away from the periphery of the isolating disc portion of the valve, allowing a flow to take place. As soon as the excess pressure in the



pipeline is relieved, the air-pressure pushes back the flexible tube and prevents further flow. The parts of the valve include a centre member of simple shape, and a flexible sleeve of chemical Neoprene or butyl rubber, plasticised PVC, Hypalon (chlorosulphonated polyethylene) or other material. The sleeve fits closely round the centre member and prevents communication across the periphery of the centre disc. A cast-iron jacket with taper end-throats houses the centre member and flexible tube and provides an annular air chamber around the central portion of the tube. **Merrill Pumps Ltd., Cavendish Road, Sheffield, 11.**

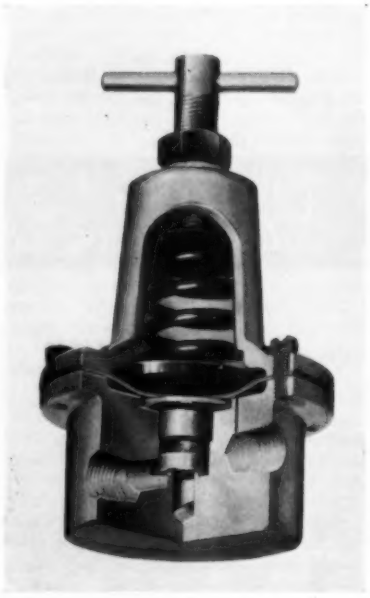
BCE 3773 for further information

Whessoe are the licensees in the United Kingdom for the diaphragm breather valve, the ST-9749, for vapour-saving storage tanks and systems, recently introduced by Shand & Jurs. Advantages claimed for it are that it maintains a good vapour-tight seal at tank pressures and vacuums less than the settings, and that its action seals against leakage through a wide range of pressures and vacuums below settings. It has been subjected to wind tunnel tests for durability and robustness. Behaviour of the pallet in the valves, Whessoe point out, may be compared to a pilot-operated valve, for at a certain point in the operating range the pallet suddenly lifts nearly wide open and gives a high rate of flow at once. If, in spite of this venting, the tank pressure continues to build up, the pallet lifts even more as the tank pressure increases, and the flow capacity increases to a point where the tank pressure is sufficiently high to hold the pallet against its top stop. When the tank pressure starts to decrease it will decrease to a point somewhat below the value at which the valve snapped open, and the pallet will slowly settle down closer to the seat. When engagement of the diaphragm seal with the seat ring is substantially complete the valve suddenly closes with a clear, clean, snap action. **Whessoe Ltd., 25 Victoria Street, London, S.W.1.**

BCE 3774 for further information

Lock-up for Diaphragm Valves

The Mason Neilan type 76 lock-up valve for use with diaphragm-operated control valves has been designed so that in the event of a failure in the operating air supply the control valve will be locked in the last position for an indefinite period, allowing the air failure fault to be located and rectified. As soon as the air supply is restored, the lock-up valve will reopen and normal process control will be re-established. It is a brass valve and is connected in the air line between the control instrument and the diaphragm connection of the control valve. The signal connection of the lock-up valve is connected to the instrument air supply. When the air supply is normal the signal pressure underneath the diaphragm compresses the spring holding the valve in the open position, thus enabling the instrument output to pass straight through to the diaphragm in the normal way. Immediately the in-



strument air supply pressure drops below a predetermined value the spring moves the soft-seated plug downwards, shutting the valve completely and locking the last instrument output pressure signal in the control valve diaphragm case. The rating of the lock-up valve spring has a range of 10-40 psi. **Crosby Valve & Engineering Co. Ltd., Ealing Road, Wembley, Middlesex.**

BCE 3775 for further information

Gate Valves

After lengthy development and field trials, Langley have introduced their new Multi-seal 17000 gate valve as a standard production line. It incorporates multiple sealing faces to prevent the scoring of the seat by foreign particles from affecting the seal. The faces are divided by labyrinths and are said to be

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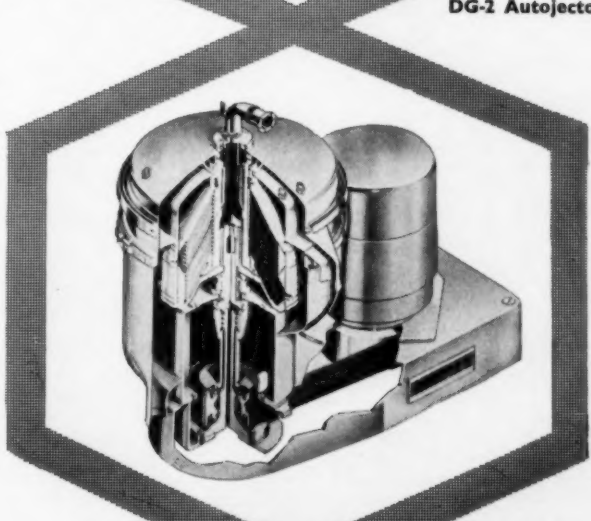
The Controlled Solids Discharge DV-2 Centrifuge purges solids from the bowl continuously by means of valves which are controlled by an external timer. Instantly variable control of solids discharge is thus at the operator's fingertips.

The DG-2 Autojector. In this case build up of solids in the bowl automatically opens the valves, which allows the DG-2 to handle variable feed material. Consistent operation without attention is ensured by this unique design.

The DH-6 Nozljector has the largest capacity of the Sharples range of nozzle discharge disc centrifuges. In fact it has a higher capacity than any other machine of this type in the world.

DG-2 Autojector



DH-6 Nozljector

SHARPLES

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PLANT EQUIPMENT NEWS

unaffected by positive or negative pressures. The seat-disc contact area has been reduced to obviate galling between alloy faces. A broach action by the wedge during the final closure has been designed to remove any build up of solids at the seat area so that slurries and liquids containing solids in suspension can be handled. A positive shut-off is claimed for a minimum stem loading. The wedge disc is manufactured completely in resistant alloy. The valve gear is designed to be only lightly stressed, so that it will readily open after being shut for long periods. **Langley Alloys Ltd., Langley, Slough, Bucks.**

BCE 3776 for further information

A range of wedge disc gate valves in forged carbon steel is being made in Great Britain by Crane, after being manufactured for some time in the U.S.A. by the parent company. They are available with screwed or socket-welding ends in sizes up to 2 in. with union or bolted bonnet, and with inside screw or outside screw and yoke. They conform to the draft British Standard for Cast and Forged Steel Valves. They can be made in other materials. **Crane Ltd., 15 Red Lion Court, Fleet Street, London, E.C.4.**

BCE 3777 for further information

No special tools are needed when closing the blind of the new Triangle oil-line blind valve. The valve uses the wedge-gate principle and, the makers state, it provides a positive, leak-proof shut-off by the line pressure exerting itself against "O" rings in the wedge-disc

faces. The body is in cast carbon steel; the blind, full-flow wedges and elevator plate in cast or forged-carbon steel; and the seal rings in synthetic rubber. **Triangle Valve Ltd., Lamberhead Green, Wigan.**

BCE 3778 for further information

An all-plastic gate valve, the Flexplug, developed by Vanton Pumps, New Jersey, is being made available in Great Britain by V. A. Howe. Constructed of PVC or styrene co-polymer, it incorporates a Teflon chevron packing for sealing, and an unrestricted flow is provided when the gate is fully open. Rated

for 150 lb. service, it can withstand temperatures up to 140° when made in PVC or of 170°F when in styrene co-polymer. The valve is offered for handling a wide range of corrosive liquids and slurries. **V. A. Howe & Co. Ltd., 46 Pembridge Road, London, W.11.**

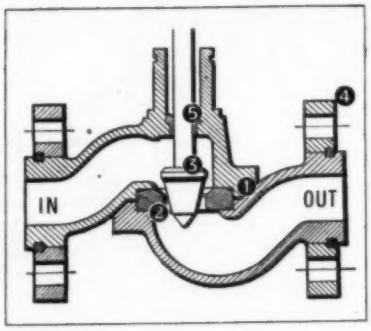
BCE 3779 for further information

The new range of Hindle-Hamer fluon-seated gate valves embodies a precision fit of the metal-to-metal contact of the wedge, and a pair of fluon packing-seals which press tight against the wedge, forming, the makers state, an impassable seal. The fluon seals are contained with their seating faces standing proud of the metal seat the requisite distance to ensure ample compression of the fluon when the valve is closed. The valves are operated in the same way as conventional gate valves, but they seal both upstream and downstream. The valves can be supplied in bronze, stainless steel or other metals to meet special conditions. **Joshua Hindle & Sons Ltd., Hindle House, Leeds, 1.**

BCE 3780 for further information

Split-body Valves

Annin valves are now being made in Great Britain by Audley under U.S. licence, and they are known as Audco-Annin valves. A feature of them is that the body is split and the single seat provides an internal contour of the same area as the relating pipe size. Pockets and shoulders have been eliminated Audley point out, and the body wall sections are cast to specifications in a variety of metals and alloys. The body flanges retain the seat ring in alignment with the valve plug, and the valve seat has been designed to be unaffected by stresses from pressure or thermal shocks and to be easily retained and removed.



The valve plugs are contoured to provide either linear, percentage or semi-throttle characteristics. The streamlined flow through the valve helps to keep body pressure drop to a minimum. Separable flanges are available on all 600-lb. ASA rating bodies in sizes 1 in. to 4 in. 150-lb., 300-lb. and 600-lb. raised face flanges can be interchanged at will. **Audley Engineering Co. Ltd., Newport, Shropshire.**

BCE 3781 for further information

Flow Divider

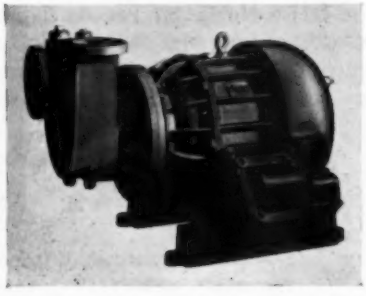
A precision-built valve, the Flow Divider, designed for the accurate division of a flow of fluid into two parts, is being made available by Integral. The flow may be divided equally or in any desired ratio, irrespective of pressure variations and differences in pressure between the two outlets, or variations in total flow, temperature or viscosity, the makers point out. The input flow range is 2½ to 6 gpm, the maximum pressure 4000 psi, and the accuracy of division is given as ±2%. **Integral Ltd., Birmingham Road, Wolverhampton.**

BCE 3782 for further information

Pumps

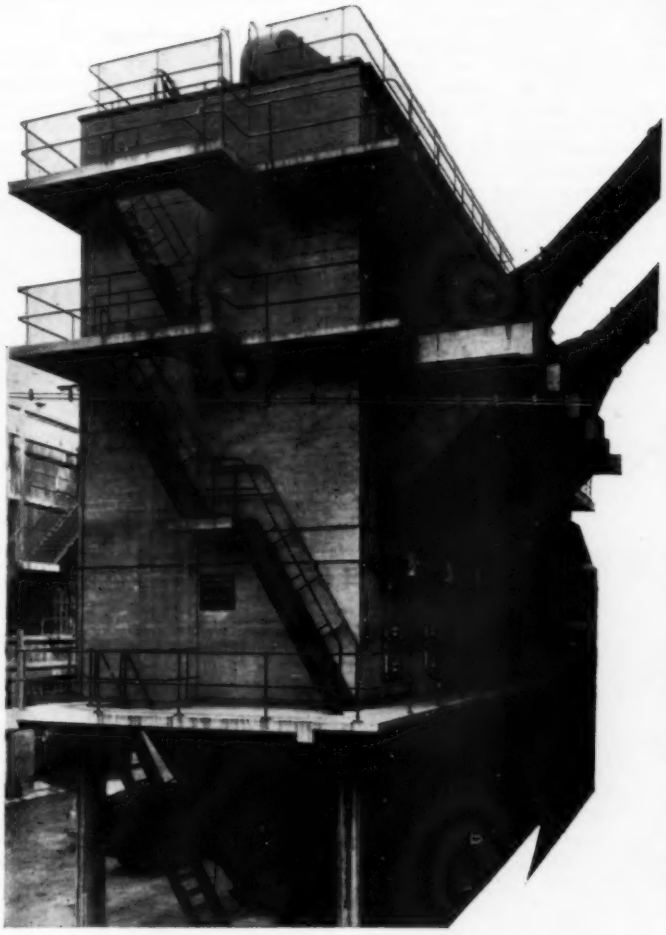
Centrifugal Pumps

The self-priming centrifugal Mopump has been developed primarily to meet the needs of the petroleum industry for handling refined fuels, but it can be used for other liquids which do not contain much abrasive solid. They were designed to provide a higher efficiency than would be expected from a self-priming pump by using a standard double-shrouded single-entry impeller and a casing capable of holding sufficient priming liquid without requiring a non-return valve. Straight vertical priming lifts of up to 15 ft on petrol present no problem for the pump. It is very deliberate and



BCE 3718 for further information

Towards clean air



By courtesy of The Morgan Crucible Co. Ltd.

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PLANT EQUIPMENT NEWS

does not suffer from rapid heating of priming liquid, the makers point out. The basic range of sizes is 2-5 in., but other sizes are available. The pumps are constructed as a unit, the motor being mounted on slide rails to facilitate internal examinations of the casing and impeller without breaking pipe joints. The impeller, of gunmetal, has an extended stem bored to suit the motor shaft and accurately finished on its outer diameter to take the mechanical seal. **Rhodes, Brydon & Youatt Ltd., Waterloo Engineering Works, Stockport, Ches.**

BCE 3783 for further information

A range of stainless-steel pumps for use in the chemical, process and food industries has been developed by Tangyes. Designed to be as flexible as possible, these units are capable of handling from 2 to 350 gpm and of developing heads of 10 to 210 ft. As the units have one bearing bracket to accommodate the five hydraulic sections, all the parts, excepting the casing and impeller, are interchangeable. They are constructed in 18/8/3 stainless steel. The impellers are of the company's patented design, which permits double shrouds without rivets, so that, it is pointed out, the whole of the impeller interior can be relieved of casting blemishes. The deep stuffing box has been designed to accommodate either soft packing or a mechanical seal, without modification to shaft or box. The standard range, type C, is intended to handle liquids at temperatures up to 230°F. **Tangyes Ltd., 60 Grosvenor Street, London, W.1.**

BCE 3784 for further information

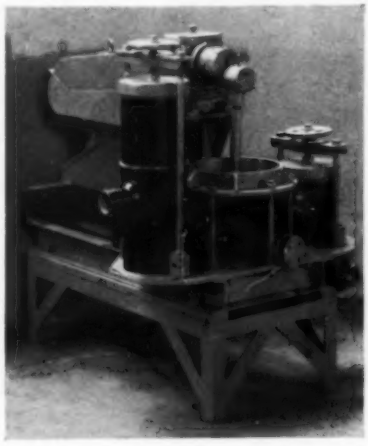
Specially developed for the chemical industry, the new Girdlestone Autostart self-priming centrifugal pump works on the recirculation principle. It has an open-type impeller, no valves and no fine working clearances. Materials of construction include stainless steel and other resistant alloys, but for normal duties it

is usually supplied in cast iron. Mechanical shaft seals are fitted exclusively and types are available for solvents and water duties, and for many acid and chemical solutions. The volute priming chamber and bearing housing with fixing feet are cast in one piece, thus reducing the number of liquid joints to a minimum and ensuring strength and rigidity. Access to the impeller and mechanical seal is obtained by removing the volute endcover. Suction and delivery are screwed 1-in. B.S.P.T. connections as standard, but can be arranged with A.P.I. thread if required. Alternative connections can be fitted. The impeller will pass small solids in suspension. Two interchangeable sizes are available and the special design promotes rapid priming, the makers point out. **Girdlestone Pumps Ltd., 23 Davies Street, London, W.1.**

BCE 3785 for further information

Acid Pumps

A diaphragm pump constructed in Keebush except for the diaphragm and ball valves, which are in synthetic rubber and flexible plastics, is being made available by Kestner for handling acids. It is glandless, and self-priming and suction lifts of 22 ft of water, the makers



say, are easily obtained. The three sizes cover the capacities 200-1500 gph at a maximum pressure of 25 psig. Drive is by electric motor or petrol engine. **Kestner Evaporator & Engineering Co. Ltd., 5 Grosvenor Gardens, London, S.W.1.**

BCE 3786 for further information

The latest addition to the Mitchell range of acid pumps is their vertical self-priming centrifugal model and it includes two types: MV/SP vertical self-priming, with either mechanical seal or packed gland, and MV/FS for use on "flooded suction" applications with either mechanical seal or packed gland. A unique feature claimed for the pumps is the hollow spindle motor drive, which enables the pump shaft to be located and driven by the motor shaft. The corundum stoneware, it is pointed out, also is alkali-proof, abrasion-resisting, non-porous, non-absorbent, resistant to high temperature and to thermal shock. The pumps prime automatically by the effect of the special design of the pump casing. After priming, no liquid circulates within the pump. The range will handle 20-100 gpm. **L. A. Mitchell Ltd., 37 Peter Street, Manchester, 2.**

BCE 3787 for further information

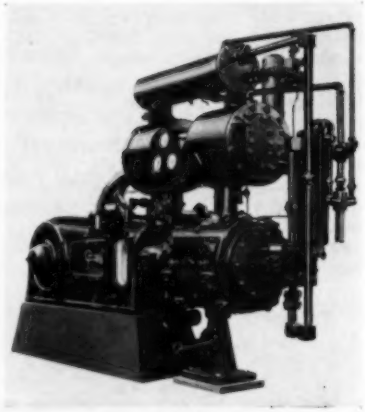
Seal-less Pump

A new seal-less pump, the Vanton Flex-i-liner, which works by a squeegee action on the fluid trapped between a liner and the pump block and was recently marketed in the U.S.A., is being made available in Great Britain by V. A. Howe. Pumping is accomplished by a rotor, mounted on an eccentric shaft, which rotates within the liner, creating a progressive squeegee action. Shaft seals and packing have been eliminated by isolating the fluid from all moving parts. The only two parts in contact with the fluids are the outer surface of the moulded flexible liner and the inner surface of the body block. The pumps are self-priming and, the makers state, will develop vacuums up to 26 in. Hg and will readily handle gas, liquid or viscous fluids. The action avoids churning or foaming of the fluid. The two parts that come into contact with the fluid being pumped may be made in a variety of materials of construction, including stainless steel and a range of plastics. The pumps are manufactured in sizes covering the range up to 40 gpm with discharge pressures up to 60 psig. **V. A. Howe & Co. Ltd., 46 Pembridge Road, London, W.11.**

BCE 3788 for further information

Gas Compressors

The new three-stage straight-line compressors recently introduced by Consolidated Pneumatic Tool are designed for the continuous compression of air or other gases to pressures of up to 1500 psi with a free air delivery of 242 cfm at that pressure. For operating periods of not more than eight hours, the compressors may be run to give 238 cfm at 2000 psi. The new compressor, the TCB



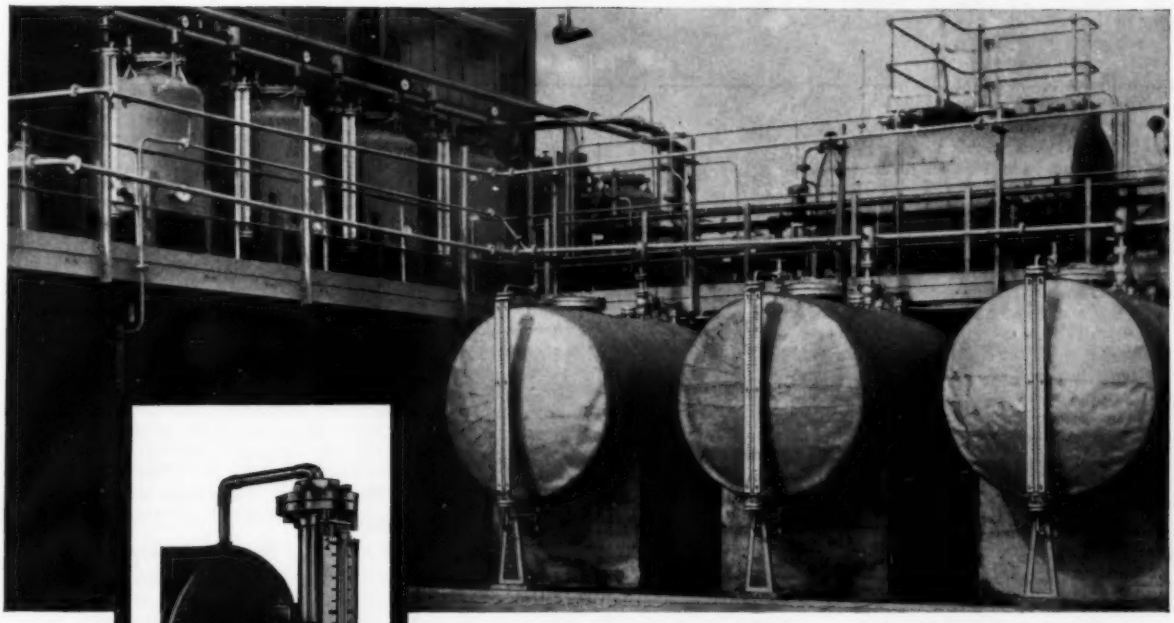
3, is a development of the class T design, using a double-acting low-pressure stage followed by a single-acting opposed second and third pressure stages. **Consolidated Pneumatic Tool Co., 232 Dawes Road, London, S.W.6.**

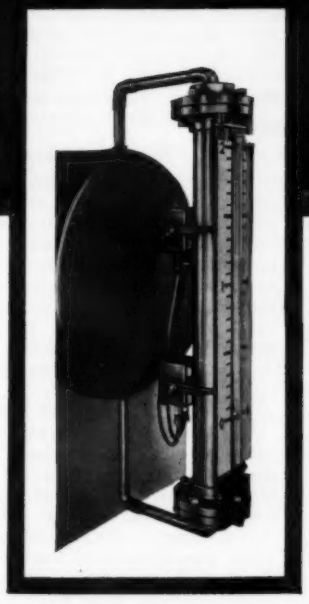
BCE 3789 for further information

BCE 3719 for further information

Safety...

in numbers





A branch tube from the storage vessel carries a magnetic float. A separate glass indicator tube carries an indicator that follows the float with complete fidelity. Alarm switches for high and low level are optional.

Write for leaflet R.P. 2045C./R.

Seven "Ekstrom" safety liquid level indicators can be seen in this photograph. But in all 25 Ekstroms are used on this Imperial Smelting Corporation "ISCEON" installation, at Avonmouth.

For the "Ekstrom" liquid level indicator is not only completely accurate and reliable but is the safest indicator available, since accidental breakage of the glass indicator tube does not cause loss of process fluid, nor interfere with the function of the alarm switches which are available.

For all installations where liquid is stored under pressure, and for toxic and corrosive fluid handling, the "Ekstrom" is, therefore, the ideal choice.

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P 4

PLANT · EQUIPMENT NEWS

The new rotary, two-stage, oil-flooded sliding vane compressors of Air Pumps are designed for mobile or stationary use and are powered by internal combustion engines or electric motors. Their capacities range from 300 cfm to 600 cfm free air delivered to B.S. 726, for working pressures up to 125 psig, and humidities of up to saturation point, altitudes up to 10,000 ft and ambient temperatures up to 125°F. They are fitted with automatic floating-speed regulation, automatic mechanical shut-down protection with indicators, cyclonic pre-cleaner oil-bath air-inlet filters to B.S. 1701 Grade "A", fuel and lubricating oil filters, and heavy-duty undercarriage with automative steering. **Air Pumps Ltd., Bushey Road, London, S.W.20.**

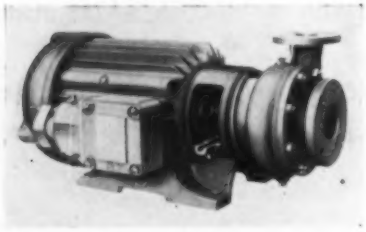
BCE 3790 for further information

In the new Portablok range of portable compressors the compressor and diesel engine are combined in one unit, utilising a common crankshaft and thus eliminating the need for couplings and allowing a degree of interchangeability of parts between the compressor and the engine never previously obtainable, the makers claim. Compressor and engine are air-cooled. The machines are for the capacities 70-140 cfm at a pressure of 100 psi and they are mounted on a trailer chassis of tubular construction, which also serves as an air receiver. **Tilghman's Ltd., Broadheath, Altrincham, Ches.**

BCE 3791 for further information

Flameproof Pump Motors

Worthington-Simpson have introduced Monobloc flameproof motors in their range of motorised pumps for the petroleum and chemical industries. The motors are totally-enclosed, fan-cooled, squirrel-cage induction models and have been designed to meet specifications for Groups I and II gases. They comply with B.S. 229: 1957 for flameproof enclosure and B.S. 2613: 1957 for electrical performance. The sizes range from 1-7½ hp, 1450 rpm; and 1½-12½ hp, 2900 rpm.



The enclosure is of substantial construction to withstand rough usage. The latest addition to the company's pump range is a model constructed in Hastelloy B. The company's chemical pumps cover capacities up to 675 gpm, with heads up to 125 ft. **Worthington-Simpson Ltd., P.O. Box 17, Newark-on-Trent, Notts.**

BCE 3792 for further information

Tower in Transparent Plastic

Transparent corrugated rigid vinyl sheet was chosen for the curtain walling of the 67-ft tower recently erected at the works of F. W. Berk & Co. Ltd., London, E.15, to the architectural design of the company's engineers to house remotely-controlled plant. The plastic material was selected because of its durability to the corrosive conditions associated with the plant and because of its excellent transmission of light to the interior of the building. Although the plastic sheeting is more expensive than conventional materials, the company expect to recover the extra cost through its long life. The tower's framework is of steel sections, protectively coated by Berk's Schori Division, and the amber-coloured plastic sheeting (Cobex) was supplied by **BX Plastics Ltd., Higham Station Avenue, London, E.4.**

BCE 3793 for further information

Hydraulic Motor

The Staffa hydraulic motor is a slow-speed high-torque power unit working from a variable delivery pump. It has five cylinders of 4-in. bore and 3-in. stroke. These drive a crank shaft by slipper-type conrods thrusting against an eccentric on the shaft. The unit is enclosed in a split crank case which facilitates assembly. The motor has been designed to work at a pressure of 1500 psi and to run at a maximum speed of 50 rpm—when the output is about 31 bhp. **Chamberlain Industries Ltd., Staffa Road, London, E.10.**

BCE 3794 for further information

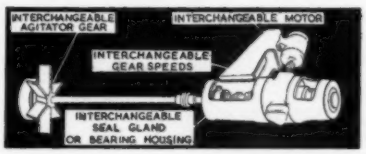
Compression Joints for Nylon Tubes

For jointing nylon tubing Compression Joints have designed and patented a tube nut type of compression fitting, Nitex, manufactured from high-quality brass. It allows the degree of compression to be controlled. Moreover, no special tools are required in its use and the joint can be made, broken and remade without impairing its efficiency. No distortion of the ferrule occurs, the makers point out, and the ferrule incorporates a tube liner which prevents collapse of the tube on compression. The fittings are also suitable for use with copper tubes in fractional O.D. sizes. **Compression Joints Ltd., Tyburn Road, Erdington, Birmingham, 24.**

BCE 3795 for further information

Heavy-duty Mixer

Mitchell's Majormix mixer has been developed to provide a robust machine which can be easily modified in speed and agitator arrangement. Standard totally enclosed or flameproof motors of up to 15 hp can be used as prime movers, and agitator shaft speeds from 17 to 420 rpm can be obtained by fitting the appropriate pair of change wheels into the change-wheel box. The base of the machine can accommodate either a bearing for open-top vessels or a gland or mechanical seal for pressure or vacuum vessels. Components have



been designed where possible on the cartridge assembly principle for speed in maintenance. **L. A. Mitchell Ltd., 37 Peter Street, Manchester, 2.**

BCE 3796 for further information

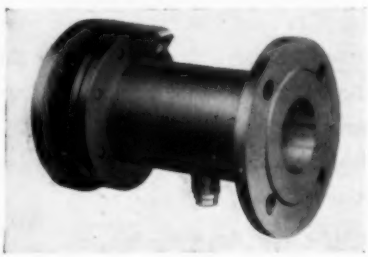
New Lead Alloy

Antatac R.1 is a new lead alloy developed by British Lead Mills to counteract a small but increasing number of inexplicable failures in chrome tank linings. It is available in the form of sheet for linings and pipe for heating and cooling coils, and anodes. **British Lead Mills Ltd., Byron House, 7 St. James's Street, London, S.W.1.**

BCE 3797 for further information

Bellows Expansion Joints

Samsons are making available a new metal bellows expansion joint for which the following advantages are claimed: (1) automatic centring of the bellows because of even external compression; (2) frictionless movement as the medium being passed forms a cushion between the bellows and outer casing; and (3) insulation in the same way as a pipeline.



Samson Controls Ltd., 19 Borough High Street, London, S.E.1.

BCE 3798 for further information

VACUUM DRYING?

Yes, it's one of our Interstitial Vacuum Driers. Well, no, we don't *quite* understand it all, but our technical experts are very pleased with it. We've had it on the market for about a year, now, and we're getting no end of people asking about it. You see, there's a series of steam jacketed trays in completely self-contained compartments, housed in one large drier, and that means you don't have to fill every tray before you start the machine — you can go on loading and unloading them individually, any time you like. And the hot vacuum steam comes in direct contact with the tray bottom and the heat does not have to pass through any air space — our technical people are very proud of that, too. Now, they've come along with all these figures about the machine's performance — blinded us with science, in fact. If you're interested, why don't you have a word with them? They'll be able to tell you a lot more.

Calmic Vacuum Drying Facts

Material	Temperature	Loading lbs./sq. ft.	Moisture Initial	Moisture Final	Drying time
Protein Hydrolysate	90°C	2.63 lbs. DRY	16.1%	5.05%	5 hrs.
Pork Pancreas	35°C 55°C	1.3 lbs. DRY 1.3 lbs. DRY	63% 70-75%	1% 3%	24 hrs. 10 hrs.
Calcium Glycerophosphate	50°C	2 lbs. WET	15% solids	11.2% mc	12 hrs.
Oblivon Carbonate	35°C	6.15 lbs. WET	10.25%	1%	13 hrs. 55 mins.
Medicinal Barium Sulphate	95°C	1" deep WET	43%	.033%	1¼ hrs.
Sodium Alginate	65°C	4.61 lbs. WET	8.25%	4.4%	12¼ hrs.
Titanium Oxide	100°C	11.17 lbs. DRY	41.5%	0.0875%	23 hrs.
Lithium Hydroxide	50°C	3.08 lbs. WET	4.3%	0.9%	4¼ hrs.
Optical Bleach	70°C	6.15 lbs. WET	40%	10%	19 hrs.

Material	Temperature	Loading lbs./sq. ft.	Moisture Initial	Moisture Final	Drying time
Copper Oxychloride	90°C	7.05 lbs. DRY	40.2%	.875%	15¼ hrs.
Silver Nitrate	90°C	7.1 lbs. WET	2.5%	.05%	3¼ hrs.
Arsenic Acid	80°C	2¼ lbs. DRY	64% AS_2O_5	83.5% AS_2O_5	58¼ hrs.
Piperazine Hexahydrate	38°C	4 lbs. WET	10%	116% DRY	12 hrs.
Zinc Bacitracin	35°C	0.4 lbs. DRY	73%	5%	24 hrs.
Ferrous Succinate	95°C	1.5 lbs. DRY	45% inc. bound.	18.8% inc. bound.	4 hrs.
Thiram Goulac Mix	50°C	1.35 lbs. DRY	46%	1.7%	5 hrs.
Soup Mixture	70°C	2.31 lbs. WET	14.9%	1.7%	5 hrs.
Sodium Metaborate	50°C	2 lbs. DRY	8.1 Mols/H_2O	3.91 Mols/H_2O	12¾ hrs.

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PLANT EQUIPMENT NEWS

Instruments

Level Indicators

Blaw Knox announce the development of a new level indicator for liquids, powders, granules and flakes in pneumatic conveying-systems. It is a double-diaphragm instrument specially designed to be unaffected by build-up of air pressure or dense dust within a silo. The diaphragms are arranged vertically and are coupled by a spring-loaded even beam connected to micro-switches. As material within the silo rises and covers the lower diaphragm, its weight deflects the diaphragm which rocks the beam and trips one or more of the micro-switches to stop the flow or actuate warning devices. Conversely, as material level falls and weight is removed from the lower diaphragm, the spring-loaded beam resumes its original position and operates the switches. For extreme conditions, i.e., in high temperatures or when handling unusual materials, special diaphragms can be supplied. **Blaw Knox Ltd., 94 Brompton Road, London, S.W.3.**

BCE 3799 for further information

A new single-level liquid-level switch, suitable for one-, two- or three-level operation, has been designed by K.D.G. The internal arrangement consists of a metallic diaphragm which distends proportionately to the head of liquid in the tank and so actuates the switch mechanism. The support casting is of brass and the weatherproof cover is of cast aluminium. **K.D.G. Instruments Ltd., Manor Royal, Crawley, Sussex.**

BCE 3800 for further information

Firth Cleveland Instruments, a subsidiary of Simmonds Aerocessories Ltd., have concluded a licensing agreement with the Gilbert & Barker Manufacturing Co., Massachusetts, U.S.A., to manufacture and market the Gilbarco electronic tank contents gauge. The essential components of the gauge are the sensing element and the electronic servo-unit. The sensing element is a small cylinder, at the lower end of which is an antenna $\frac{1}{4}$ in. in length, which maintains a fixed penetration in the liquid to a depth of approximately $\frac{1}{16}$ in. Minute radio-frequency signals are transmitted from the electronic control to the antenna, which emits a variable return signal. The strength of this return signal strengthens if the level of the liquid falls, leaving less of the antenna in the liquid. The return signal weakens when the liquid level rises. The variation in the strength of the return signal is conveyed to the electronic servo-unit, where a servo-motor reacts to adjust the position of the sensing antenna to the same fixed depth of penetration in the liquid. Connected to the servo-motor is a mechanical indicator, reading in feet, inches and sixteenths, with fractions spaced widely enough to permit $\frac{1}{32}$-in. readings. On many installations in the United States the instrument has recorded greater accuracy than $\pm\frac{1}{16}$ in. It can be installed in tanks of all types at temperatures up to 425°F. **Firth Cleveland Instruments Ltd., Treforest, Glamorgan.**

BCE 3801 for further information

J. Edward Hall announce the addition to their existing range of instruments of the Proxicon Mark III dust and weather-proof industrial level controller. It replaces the Mark II model. A capacitance type of instrument, it is designed for use with any liquid or free-flowing solid. There are no moving parts in the container. **J. Edward Hall Ltd., Clarence Road Works, Leeds, 10, Yorks.**

BCE 3802 for further information

Alto Instruments have commenced the full manufacture in this country of the Altoflux induction flowmeter in association with N.V. Alto, of Amsterdam, Holland. The Altoflux is being manufactured in the U.K. initially for pipelines up to 9-in. and later, in diameters of several feet. **Alto Instruments (Great Britain) Ltd., Maxwell House, Arundel Street, London, W.C.2.**

BCE 3803 for further information

G.E.C. have made available a photo-electric smoke-density indicator capable of displaying continuously the flue gas density existing in a smoke stack or flue. It is constructed to the British Standard 2811 : 1957 and is suitable for use in all types of heating installation, where solid or liquid fuels are burned. It incorporates a printed circuit wiring. **The General Electric Co. Ltd., Magnet House, Kingsway, London, W.C.2.**

BCE 3804 for further information

Basic Airmec analogue equipment, consisting of a computer amplifier, a drift correction amplifier and two power units, has been designed so that a computer system of any size may be developed to conform to any specific requirement. A detachable problem board on which resistors, capacitors and potentiometers can be fitted makes it possible to set up a wide variety of problems. **Airmec Ltd., High Wycombe, Bucks.**

BCE 3805 for further information

Pressure gauges having a stated accuracy of $\frac{1}{4}\%$ up to 1000 psi and of 1% up to 10,000 psi have just been made available by Negretti & Zambra under the range name "IVIX". They are available in sizes 4 in., 6 in. and 9 in., for projection or flush panel mounting and with bottom or back entry. They are made to B.S. Specification employing diaphragm movements up to 30 psi and Bourdon tube movements up to 10,000 psi. All are fitted with zero adjusters and the movements are mounted on sub-bases. **Negretti & Zambra, 122 Regent Street, London, W.1.**

BCE 3806 for further information

New Publications

A handy and informative guide to polythene corrosion-resisting tubes and fittings has just been released in catalogue form by the Chemical Pipe & Vessel Co. Ltd. Entitled "Plumbing in Polythene", the guide gives such details of installation, welding and chemical and physical data of tubes and fittings of this material. **Chemical Pipe & Vessel Co. Ltd., Godstone Road, Henley, Surrey.**

BCE 3807 for further information

"This is TI today" is the title of a booklet issued by Tube Investments Ltd., and which lists the names and addresses of TI's companies and the range of products offered by them. **Tube Investments Ltd., The Adelphi, London, W.C.2.**

BCE 3808 for further information

Three new publications from Sturtevant have recently been received on equipment which is directly concerned with the reduction of air pollution. These are as follows: 7013—the "Ludgate" Mechanical Dust Collector; 3503—the "Newgate" Grit Collector; and 6510—Sturtevant Scrubbers. Copies from **Sturtevant Engineering Co. Ltd., Southern House, Cannon Street, London, E.C.4.**

BCE 3809 for further information

We recently received an interesting publication from the American Chemical Process Co. dealing with the uses of ion-exchange resins in treating sugar-bearing liquids. This 14-page booklet was prepared by the company's associate technical director, Dr. Irving M. Abrams, and covers the demineralisation of extracts of beets and cane, the economics of using ion exchange and methods, results, problems encountered in commercial applications and a solution to each problem is reviewed. Entitled "Refining Sugar Solutions with Duolite Ion-exchange Resins", copies may be obtained from **G. F. Stoneman, Chemical Process Co., 1901 Spring Street, Redwood City, California.**

BCE 3810 for further information

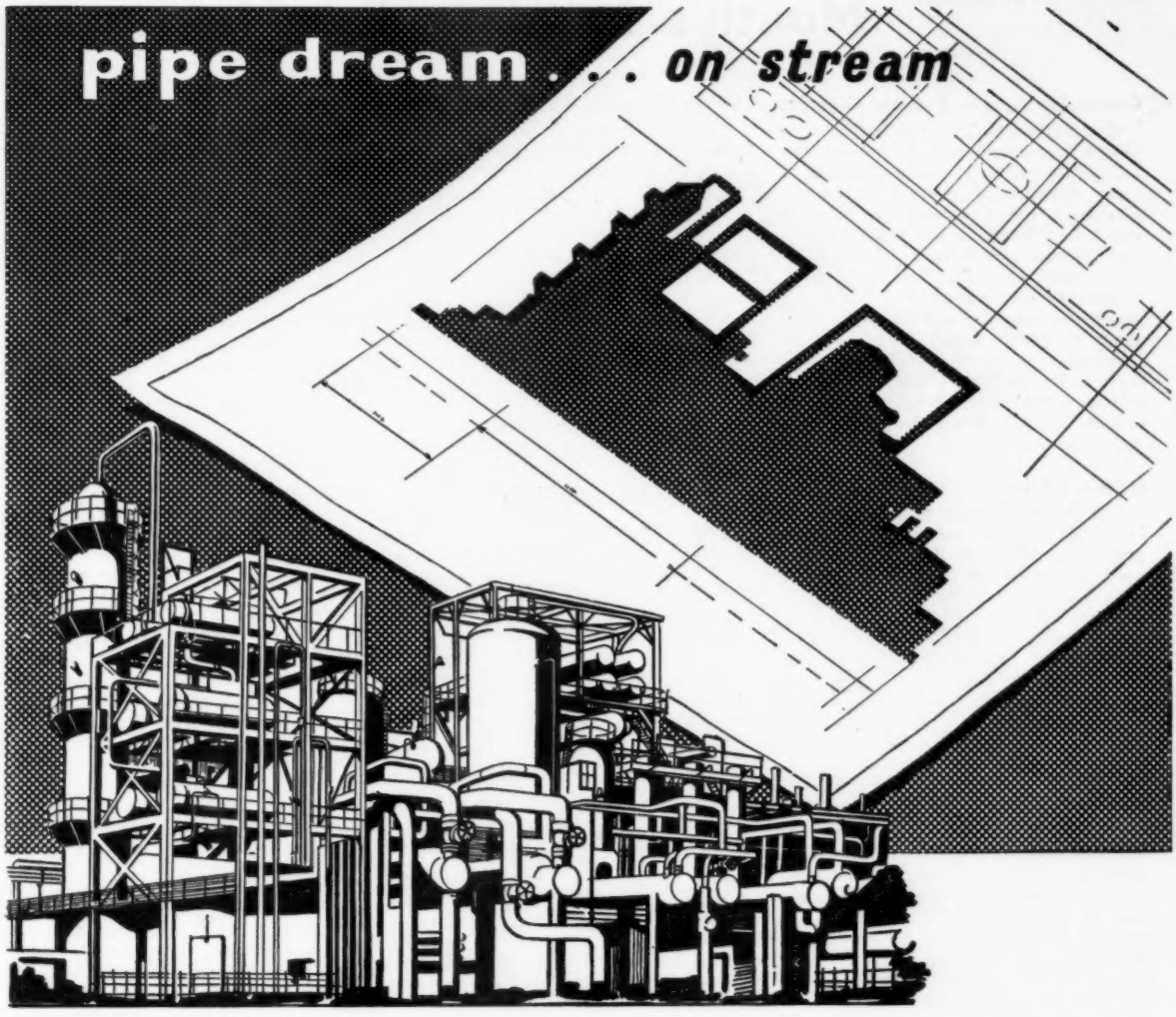
For the first time since its formation, the Elliot-Automation Group have produced in one publication an account of the wide range of equipment provided by the group. Copies from **Elliott-Automation Ltd., Century Works, Lewisham, London, S.E.13.**

BCE 3811 for further information

The history of Whessoe is a fascinating account, tastefully illustrated, of the origins of this well-known company. From the manufacture of small repair parts for cisterns and farm gear to today's massive wind tunnels built by the company for R.A.E. Bedford, the book records in an easy-to-assimilate style the growth of Whessoe from an ironmonger's shop opened in 1790 in Tubewell Row, Darlington, to the company which now employs some 1800 people in works at home and abroad. Copies from **Whessoe Ltd., 25 Victoria Street, London, S.W.1.**

BCE 3812 for further information

BCE 3721 for further information



Somewhere in the Middle East, CJ.B. men work to finish a pipeline—rugged almost unmapped country. In an office in London, long after hours a team is working out a complex chemical-process flow-sheet. Elsewhere a CJ.B. survey team may be working on a project to bring natural resources, gas or mineral to everyday use in the world.

In Sheffield, engineers and metallurgists are working on the mechanical solution of some complex atomic or aeronautical research problem.

CJ.B. embraces all the necessary resources of vision, technical flair and engineering skills together with financial administrative and executive ability to handle such projects from beginning to end—under one responsibility.

Something of the width of this service to science and industry is outlined in the Company's brochure No. C.E.01, a copy of which is available to senior executives with projects requiring technical and physical solution.

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Month's News in Brief

Courtaulds Secure Russian Contract

Courtaulds Ltd. have successfully concluded negotiations with Technopromimport, Moscow, for a contract, valued at some millions of pounds, to supply machinery for a factory to be constructed in Russia which will manufacture cellulose acetate yarn from Russian-made raw materials. Courtaulds have undertaken the responsibility for supervising the erection of the machinery, some of which will be fabricated in Courtaulds' Coventry workshops; and some to be supplied by other U.K. firms to Courtaulds' requirements and specifications, and for putting the acetate yarn factory into production.

Golden Jubilee

The British Tabulating Machine Co. Ltd., which this year celebrates its golden jubilee, and Power-Samas Accounting Machines have reached an agreement in principle for a merger between the two companies. However, a joint statement issued by Sir Cecil Weir, chairman of British Tabulating, and Mr. A. Terence Maxwell, chairman of Powers-Samas, warns that full details of the merger will take some time to prepare and probably will not be completed until early next year.

Diamond Jubilee

The diamond jubilee of the campaign for clean air is to be celebrated next year with an international conference and exhibition in the Seymour Hall, London, October 20 to 23, 1959. Announcing this, the National Society for Clean Air also states that Sir Hugh Beaver, chairman of the Government Committee that has seen its recommendations embodied in the new Clean Air Act, has accepted an invitation for nomination as the next President of the Society, to succeed Dr. R. Lessing, C.B.E., whose two-year term of office ends in October next, during which month the Society will hold its conference (October 1 to 3) in Llandudno.

A 75th Anniversary

The Alfa-Laval/De Laval Group of Companies have issued a souvenir brochure to celebrate the 75th anniversary of their formation. The parent concern, the Separator Co., Stockholm, was formed in 1883 to exploit Dr. Gustav De Laval's invention of the first continually-operating cream separator. From these early beginnings there has developed a world-wide organisation with factories throughout Europe, North and South America and the British Commonwealth, with branch offices in many other territories. The British Alfa-Laval organisation has factories at Brentford, Middlesex, and Cwmbran, Monmouthshire, and has an extensive production of milking machines, centrifugal separators, filters, pumps and heat exchangers.

Linings Department Extended

To meet the growing demands for protective plastic linings in industrial plant, the Ensecote Department of Newton, Chambers & Co. Ltd., at Thorncliffe, near Sheffield, has been modernised and largely re-housed. Emphasis on research and development is made at the Company's Ensecote Department to discover better methods of applying and to improving still further the quality of the linings affixed to industrial equipment and tanks. These linings, say the company, are designed for use at fairly high temperatures and to give complete protection against corrosive conditions experienced in a wide range of industries.

News Briefs

Boots Pure Drug Co. Ltd. have awarded a contract for the supply and erection of extensions to their works at Nottingham to W. J. Fraser & Co. Ltd., Romford, Essex.

The Royal Society for the Prevention of Accidents has adopted as its slogan for this year's National Industrial Safety Week (September 29 to October 4) "Extra Care Stops Falls". Official figures show that, in 1956, 22,548 persons were absent from work as a result of injuries following falls, equal to 14.1% of all reported accidents.

Birmingham College of Technology is to organise a series of one-day conferences on electronic digital computers and their industrial applications. The first in this series, with special reference to Ferranti computers, will be held on October 8. Full details from the Registrar, Birmingham College of Technology, Gosta Green, Birmingham, 4.

Holborn College of Law, Languages and Commerce, Princeton Street, London, W.C.1, is to start classes in September next for scientists and technologists who wish to learn Russian. Full details from the Principal, Dr. D. H. Smith.

The Borough Polytechnic has arranged a course of ten lectures on "Refractories, their manufacture, properties and applications". Full details from The Secretary, Borough Polytechnic, Borough Road, London, S.E.1.

The London Section Exhibition Committee of the Oil and Colour Chemists' Association has announced that the preliminary arrangements for the Eleventh Technical Exhibition, 1959, have now been completed. The venue will once again be the New Hall of the Royal Horticultural Society at Greycoat and Elverton Streets, London, S.W.1, and will take place on March 17, 18 and 19, 1959.

Associated Chemical Cos. Ltd. announce that the sales of products manufactured by British Chrome & Chemicals Ltd. and Brotherton & Co. Ltd. will be handled by a newly-formed subsidiary company, Associated Chemical Companies (Sales) Ltd., with its registered office at Brotherton House, Westgate, Leeds, 1 (P.O. Box No. 6, Tel. Leeds 29321/8).

T. Giusti & Son Ltd., Belle Isle Works, 210-212 York Way, King's Cross, London, N.7, have drawn our attention to the incorrect spelling of the company's name in the review article of the recent chemical engineering exhibition, published in our August issue, page 440, line 7, under the title "Fabrication".

Borax Consolidated Ltd. announce that the address of their Midlands branch sales office has been changed to Griffin House, 18/19 Ludgate Hill, Birmingham, 3. The telephone number (Birmingham Central 2328) remains unchanged.

People in the News

The Board of Trade announces that the **Earl of Halsbury** will retire from the position of managing director of the National Research Development Corporation on March 31, 1959, to take up another appointment. Lord Halsbury, who was only 40 when he became the Corporation's managing director in 1949, brought to this experimental organisation a considerable experience in industry both on the research and on the commercial and administrative sides, and has, through the Corporation, contributed greatly to the development of Britain's computer industry. A man of wide interests, Lord Halsbury is also president of the Institution of Production Engineers, chairman of the National Institute of Industrial Psychology, chairman of the Science Museum Advisory Council, vice-president of the Parliamentary and Scientific Committee, vice-president of the Royal Institute of Philosophy, a member of the Court of Governors of the Manchester College of Science and Technology, of the Council of the Royal Society of Arts, of the Mechanical Engineering Research Board and of the Manchester Joint Research Council.

Mr. R. T. Hayes has been appointed a director of United Coke & Chemicals Co. Ltd., a subsidiary of The United Steel Companies Ltd. Mr. Hayes, who joined the United Steel group in 1946, is commercial manager of United Coke & Chemicals, and of United Steel's Ore Mining Branch and the Santon Mining Co. Ltd.

Goodyear Pumps Ltd., one of the Holman Group of Companies, of Camborne, Cornwall, announces the appointment, as general sales manager, of **Edward H. Curry.**

Mr. P. H. D. Ryder has been appointed chairman of Q.V.F. Glastechnik G.m.b.H., the German subsidiary company of Q.V.F. Ltd. Mr. Ryder is managing director of Thomas Tilling Ltd. and chairman of James A. Jobling & Co. Ltd. He has been appointed in

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RC.186

succession to **Sir Graham Cunningham**, chairman of Triplex Holdings Ltd. and Q.V.F. Ltd.

As part of a planned expansion policy, Michigan (Great Britain) Ltd. announce the appointment of **Mr. Peter J. Messenger** to their Export Division.

Bakelite Ltd. announce that **Mr. G. Dring**, who has been a director since 1942, has retired from the board. He will continue to serve the company in a non-executive capacity as technical consultant with regard to research, patents, trade-marks and other matters and will continue to represent the company in various technical and scientific activities, both at home and abroad.

Mr. E. B. Wastell, general manager of the Selby, Yorks, works of John & E. Sturge Ltd., has retired at the age of 65. He joined the firm in 1911 to work in the laboratories at Lifford, and later became works manager of the Wheeleys Lane, Birmingham, works, a position he held until the beginning of the last war. He was largely responsible for setting up the citric acid plant at Selby during 1939-40, and under his guidance the production of citric acid has been increased to five times the original output.

Mr. L. Dobson has been appointed engineering director of the Plastics Division of I.C.I. Mr. Dobson graduated from Cambridge with first-class honours in mechanical sciences and, after spending two years at Mather & Platt Ltd., joined the Engineering Department of the Alkali Division of I.C.I. In 1941 he was engaged in the construction of the polythene plant at Winnington, and subsequently became its first maintenance engineer. By 1952 he was chief mechanical engineer, and was appointed first head of the Division's Technical Department which was formed in 1955. A year later he became Alkali Division Polythene director, and remained in that post until the beginning of 1958, when he joined the Plastics Division as engineering director designate.

This year 86-year-old **Mr. J. Arthur Reavell** celebrates his 50 years as chairman of the company he founded in 1908, with a secretary and an engineer, the Kestner Evaporator & Engineering Co. Ltd. Today it has branches in South Africa and Australia and agents all over the world. Mr. Reavell has played a leading part in the fostering of chemical engineering education and is a founder member and a past president of the Institution of Chemical Engineers.

Mr. A. E. C. Drake has been appointed a director of The British Petroleum Co. to fill the vacancy created by the retirement of **Mr. R. Gillespie** from the board. Educated at Shrewsbury and Pembroke College, Cambridge, where he obtained an Honours Degree in Modern Languages and Law, Mr. Drake joined The British Petroleum Co. (then Anglo-Persian Oil Co.) in 1935. In the previous year he had qualified as a chartered accountant, being awarded the William Quilter prize in the Institute's Final Examination. During 1948 and 1949 Mr. Drake successfully conducted important negotiations with the Syrian Government on behalf of Middle East Pipelines Ltd. In 1950 he was appointed general manager in Iran and Iraq. In the 1952 New Year's Honours, Mr. Drake was awarded the C.B.E., and in that year he was appointed representative for the company in New York. On his return to the United Kingdom in 1954, he became general manager, Supply and Development Division and, in February, 1957, was appointed a director of BP Trading Ltd., The British Petroleum Co.'s principal trading subsidiary.

Mr. A. C. Brown, formerly chief engineer of Birwelco Ltd., has been appointed deputy general manager and general sales manager of the company. **Mr. G. E. Corbett** replaces Mr. Brown as chief engineer; **Mr. J. Millward** has been appointed technical manager of Furnace Division; and **Mr. V. D. Daft** has been appointed project manager to deal with sales estimating and tendering.

A. E. C. Drake.

A. C. Brown.

M. E. O'K. Trowbridge

J. J. Serrel.

Sharples Centrifuges Ltd. have announced the appointment of **M. E. O'K. Trowbridge** as managing director of the company, and the appointment of **Mr. J. J. Serrell** to the board of the company. Mr. Trowbridge joined Sharples in 1953 and was appointed technical and sales director. He has spent a considerable time in the United States, and has travelled widely throughout the world. Mr. Trowbridge is also well known for his articles on chemical engineering subjects in the technical press, and readers will recall his articles on centrifuges which were published in the June and July, 1956, issues of *British Chemical Engineering*.

Mr. J. J. Serrell graduated from Cornell University as a chemical engineer, and subsequently did post-graduate work at the University of Pennsylvania. Mr. Serrell has been with the Sharples organisation for over 20 years, and is the vice-president of The Sharples Corporation, with responsibility for all overseas operations.

Mr. N. Maggs has joined the Systems Engineering Division of Electroflo Meters Co. Ltd. as contracts engineer.

Sir John Cockcroft has been awarded the 1958 Niels Bohr medal for special contributions towards peaceful uses of atomic energy.

Dr. W. E. Ripper, former vice-chairman and scientific adviser of Fisons Pest Control, has been appointed managing director of Dow Agrochemicals.

Sir Hartley Shawcross has been appointed a director of The Shell Petroleum Co. Ltd.

Mr. H. B. Locke, late of the Chief Scientist's Division, Ministry of Power, has joined the Carbonisation Department of the National Coal Board in the Development and Planning Branch.

This Month's Events

Home

August 27. *British Association for the Advancement of Science. 120th Annual Meeting:* At Glasgow, Scotland, **until September 3.**

August 27. *International Symposium on Combustion, organised by the Institute of Fuel:* Registration on August 27 at the Institute of Fuel, on August 28 at the Royal Institution. Technical Sessions from September 1 to 3 at the Playhouse, Beaumont Street, Oxford.

September 5. *ASLIB Annual Conference, organised by the Association of Special Libraries and Information Bureaux:* At University of Nottingham **until September 8.**

Overseas

September 1. *Meeting on Analogue Computation:* At Strasbourg, Germany, **until September 9.**

September 1. *The 2nd International Conference on the Peaceful Uses of Atomic Energy. Sponsored by United Nations:* At Geneva, Switzerland, **until September 13.**

September 4. *International Conference on Air Pollution. American Society of Mechanical Engineers:* At New York, N.Y., **until September 5.**

September 7. *World Power Conference. Sectional Meeting:* At Montreal. Details from World Power Conference, Canadian Committee, Room 500, 150 Wellington Street, Ottawa 4, Canada, **until September 11.**

September 8. *The 31st International Congress of Chimie Industrielle:* At Brussels, Belgium, **until September 14.**

September 11. *The 77th Annual Meeting of the Society of Chemical Industry to be held in Canada:* Details from Chairman, Registration Committee, Canadian Conference Committee, The Society of Chemical Industry, 14 Belgrave Square, London, S.W.1.

September 11. *The 6th General Assembly and 7th Technical Meeting of the International Union for the Conservation of Nature and Natural Resources:* At Athens, Greece, **until September 19.**

September 15. *Instrument — Automation. International Conference and Exhibition:* At Philadelphia, Penn., U.S.A.

September 15. *International Congress on Ceramics:* At Wiesbaden, Germany, **until September 20.**